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ABSTRACT

This study identified and conceptualized evidence of ideas about the nature of science to which elementary school students are exposed and the manner in which teachers provided these ideas. This was accomplished by developing a scheme for observing/analyzing classroom interaction (classroom dialogue and science activity). The scheme is theoretically based in science philosophy, particularly that of Norwood Russell Hanson, who characterizes two extreme views of science discerned in the work of practicing scientists: sensationalism and formalism (and a balanced or "via media" view). By adapting Hanson's work to the context of elementary school teaching and analyzing the discourse of four elementary science lessons (included in appendices), a set of observation clues for identifying Hanson's views were developed and refined. The clues, which comprise a nine-category analytical scheme, identify and characterize the polar views of sensationalism and formalism and reveal that "via media" views about science are being developed during ordinary science lessons. The scheme further indicates that students become aware of these ideas about science through observation, explanation, and experimentation. Results of two independent judges indicate that the clues are recognizable in the discourse of science lessons by persons other than the developer. The study concludes by examining the scheme's potential for understanding/improving science education practice. (Author/JN)

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# TOWARD UNDERSTANDING THE IDEAS ABOUT SCIENCE COMMUNICATED BY ELEMENTARY SCHOOL TEACHERS

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by

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A Thesis submitted in conformity with the requirements
for the Degree of Doctor of Education in the
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# ABSTRACT

This study identifies and conceptualizes the evidence of the ideas about the nature of science to which elementary school pupils are exposed and the manner in which teachers provide for these ideas. This is accomplished by developing a scheme for the observation and analysis of classroom interaction -- both teacher-pupil dialogue and science activities -- as these occur during science lessons.

The scheme is based theoretically in the philosophy of science, particularly in the work of Norwood Russell Hanson. Hanson tries to distinguish between views of science discerned in the work of practicing scientists by characterizing two extreme views of science, sensationalism and formalism, and a balanced or via media view. He also uses a number of science activities (such as observation, verification, experiment) as categories to organize his comparisons. By adapting Hanson's work to the context of elementary school teaching and by analyzing the discourse of four elementary science lessons, the investigator develops and refines a set of observation clues for identifying Hanson's three views. The clues, which comprise a nine-category analytical scheme, identify and characterize the polar views of sensationalism and formalism and reveal that via media views about science are being developed during ordinary science lessons. The scheme further indicates that the pupils become aware of these ideas about science through the activities of observation, explanation, and experimentation.

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Two independent judges were called upon to assess the clarity of the clues which comprise the scheme. The results of this judgement reveal that the clues are recognizable in the discourse of a science lesson by persons other than the developer.

The study concludes by examining the potential of the analytical scheme for understanding and improving science education practice.

Author: Lila F. Wolfe

Thesis Title: Toward Understanding The Ideas About Science Communicated By Elementary School Teachers

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# CHAPTER I

# RATIONALE FOR THE STUDY

## Introduction

This study is concerned with ideas about the nature of science, specifically with the manifestations of such ideas in elementary school classroom teaching. The work reflects the investigator's long standing professional and intellectual motivation to conceptualize, on a systematic basis, an intuitive sense that pupils seem to receive conflicting messages about the nature of science in their elementary school science lessons.

This state of affairs represents a significant problem for anyone sensitive to such matters whose professional role involves observation of teaching and the improvement of practice. None of the available schemes for observing and conceptualizing classroom teaching is designed to capture differences in "view of the nature of science" as these might be manifest in elementary school classrooms, and in such a way that teachers can be presented with systematic information about this aspect of their teaching. Accordingly, the problem addressed in this study is to develop such a scheme and to explore and document its clarity by analyzing a variety of elementary school science lessons.

The observation scheme is rooted theoretically in the philosophy of science, largely in the work of Norwood Russell Hanson. In characterizing two extreme views of science ("sensationalism" and "formalism") and a more balanced view ("middle of the channel" or "via media"), Hanson intended to capture differences between views of science as these can be discerned in the work of practicing scientists and in debate about the philosophy of science. He used a number of commonplace categories about scientific work (measurement, observation, explanation, verification, etc.) as a way to organize his comparisons. In adapting Hanson's work to the context of elementary science teaching for the present study, the investigator has developed a set of observation clues for detecting Hanson's three views, but it is based on the (appropriately) limited set of science categories "observation", "explanation", and "experimentation". The discourse in each of four elementary school science lessons has been analyzed in order to develop and refine the clues, and two independent judges have been called upon to assess the clarity of the clues which comprise the analytical scheme.

This document consists of seven chapters. The remainder of this first chapter is devoted to discussion and justification of the view of the problem and the methodology used, the claims being made, and the limitations of the study. Chapter II presents an analysis of related research and demonstrates the uniqueness of the study.

In Chapter III the theoretical basis for the observation scheme is presented through analysis of Hanson's conceptualization of scientific thought and activity, which is compared to that of two other prominent "meta-philosophers" of science (Nagel and Harré). Chapter IV continues in this vein, in that the features of Hanson's three philosophical views of science are examined as they relate to analysis of elementary school science teaching. Furthermore, a selection of science textbooks and school science programmes are reviewed to support the choice of science categories for the scheme.

The analytical scheme itself is developed, refined, and applied to the data in Chapters V and VI, which also include an examination of the results of assessment of the clarity of the scheme by the two judges. Chapter VII, then, concludes the dissertation with reflection on the results of the study and discussion of its implications for further research and for science education practice.

## View of the Problem

How does one study the development of elementary school children's conceptions of scientific thought and activity? More precisely, how does one study this phenomenon in such a way that practitioners can see, in the results, the possibility of exercising some choices about the teaching actions which influence children's conceptions?

The present section of the study is an elaboration and justification of the view of this problem which the investigator has selected, for there are alternative views. The section is presented in two parts -- the one largely theoretical and the other largely practical. In order to provide a framework for that discussion, let us consider the following diagrammatic representation, which might plausibly be thought to capture the essence of the process by which pupils' conceptions of science develop under the influence of teaching. (The diagram also suggests immediately some of the ways in which this phenomenon can be studied -- and has been studied, as will be seen in some detail in Chapter II.)

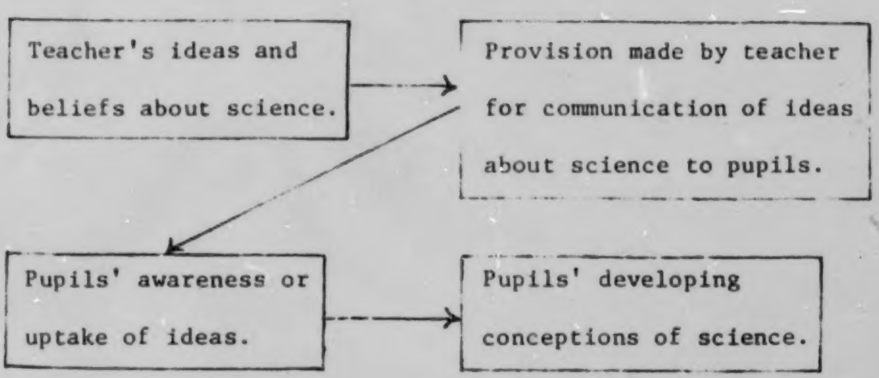
Teacher's ideas and beliefs about science.
Provision made by teacher for communication of ideas about science to pupils.
Pupils' awareness or uptake of ideas.
Pupils' developing conceptions of science.

Figure 1. Potential elements for studying children's development of ideas about science in the classroom.

Teachers, as a result of various influences, come to the classroom with a personal philosophy of teaching and learning. Such formative experiences as teacher education and course work or other experience in science have helped them acquire certain ideas and beliefs about science. Whether or not a teacher is aware of the elements and coherence of these ideas, by definition they constitute a conception or a way of conceiving the scientific enterprise to be. One way to study children's development of conceptions of science, then, is to study what their teachers' conceptions are, and how those came to be.

In the classroom, provision is made for pupils to become aware of a conception of science by the varied manner in which teachers arrange for the communication of ideas during science lesson interaction. Thus, classroom activities and teacher-pupil dialogue, as well as other teaching behaviour (such as directing pupils to selected reading materials), can be seen as provision of selected ideas about the nature of science. Clues about pupil "uptake" of those selected ideas can be discerned also in an examination of classroom activity. This constitutes a second way to study the development of children's conceptions of the nature of science -- the way selected for the present investigation.

In the longer term, the pupils' developing conceptions are seen as the "products" of teaching which are often investigated to reveal results such as attitudes about science, understandings of science, or achievement in science.

Thus, the present study focuses on the "middle" of the four-part diagram shown earlier: the substance and manner of provision of ideas about science which appear to be communicated during classroom interactions, and evidence of the pupils' awareness of the ideas. The remaining two components of the diagram are not considered in this study.

Justification for this selected view of the problem, which is elaborated in the next two sub-sections, is based partly on the theoretical soundness of investigating what is evident in classroom interactions. Systematic theoretical work which is useful for the investigator's purpose is evident in the ideas of Thomas Green, Paul Komisar, Joseph J. Schwab, and Stephen Toulmin. But there is a practical justification as well. Anyone with professional responsibility for supervision of practicing and pre-service science teachers has to provide feedback about teacher performance which is systematically linked to immediate pupil response. In contributing to that need, the investigator finds it less than helpful to study what teachers and pupils "have" as conceptions of and attitudes about science. The more important question is centered on how those conceptions develop day by day in the classroom, and on what the teacher might do in order to bring that process under control.

## Theoretical Justification

By directing this study to what is evident in classroom interaction, the investigator finds it useful to examine the ideas of Green (1968), Komisar (1968), Schwab (1962), and Toulmin (1960). Green and Komisar consider the manner in which pupils become aware of ideas and beliefs transmitted during the varied activities known as teaching. Schwab considers the various "meta-messages", or the substantive issues, about science which are unconsciously assimilated by the pupils. Toulmin examines the language and mode of explaining scientific ideas. He discusses the need for "logical asides" in order to clarify a change of meaning and context given to "ordinary" language which is used in science explanations. Collectively and independently the ideas of these theorists are directly related to the problem of the study: how teachers communicate (and may unconsciously misrepresent) ideas and beliefs about science during various teaching activities and the pupils' awareness of these ideas.

Thomas Green (1968) perceives teaching as a continuum of activities such as conditioning, indoctrination, instruction, and training -- all of which are related, and all of which involve the teacher or instructor in transmitting knowledge and beliefs to the pupil or recipient. Then, ideas and beliefs about science are being transmitted through such activities, whether or not the teacher is aware of doing so.

In analyzing the varied activities which make up the concept of teaching, Green finds certain differences in the style and degree to which each activity contributes to the belief system of the receiver. That is, the closer one gets to the concept (and activity) of teaching, the more the belief system being conveyed is based on evidence or reason. Instruction is closely associated with teaching since it involves "a kind of conversation, a giving of reasons, evidence..." (p.32) and hence the acquisition of knowledge and belief. Training, on the other hand, is associated more with forming habits and behaviours and less with the acquisition of knowledge and belief. In the same way, Green examines the activities of indoctrination and conditioning. The former is utilized to induce persons "to believe certain things" (p.33). Conditioning is applied to establish certain behaviour whether or not that behaviour is desirable. Green finds the distinctions between these activities to be unclear -- the concept of each of the others is as vague as that of teaching. Irrespective of the vagueness of these activities they are included by the teacher in what is known in everyday language as "teaching". Moreover, these activities have an important role to play since the view of the teacher is conveyed through such activities to cause change in attitudes and understandings. Since these varied activities "aim at the development of different kinds of belief systems"(Green, 1968, p.61), it follows that over the continuum of science teaching activities, teachers foster certain beliefs or ideas about science among their pupils. Then, there is justification for investigating what different ideas and beliefs are being conveyed and how they are provided for by the teacher.

Paul Komisar (1968) separates the idea of pupil awareness from that of pupil learning by arguing that what happens during teaching results in pupils' "uptake" or their immediate perception of the ideas being conveyed,not "the facts" of the ideas. In marking this difference Komisar's thesis provides a sound basis for investigating the evidence of pupils' awareness rather than the product of their learning.

Komisar analyzes the teaching act as it relates to pupil learning and in doing so he argues against the prevalent notion that teaching acts automatically result in pupil learning. In fact Komisar considers it unfortunate that the presence or absence of learning provides the basis for evaluating both the teacher and the act of teaching (p.67). On the contrary, the act of teaching results in pupil awareness. Learning, which is an objective of some forms of teaching, is conditional on pupil reproducibility of what is learned (beyond awareness) which can be accomplished only if the learner so desires (among other conditions). The teacher, then, cannot determine whether or not pupils will learn and reproduce that which is presented during lessons. On the other hand, intellectual teaching acts, such as demonstrating, proving, or explaining, require for their accomplishment an "auditor" (or learner) who becomes aware of that which is being taught. (Indeed, those intellectual acts to which Komisar refers are all included in the acts of teaching found in the elementary classroom.) The teacher, then, can (and does) exercise control over "auditor-uptake" merely by presenting ideas to pupils in the variety of ways which mark teaching acts. Komisar puts it this way:

> Success in performing the act requires success in bringing about the appropriate kind of awareness....The teacher cannot be successfully introducing a topic to a student without its being the case that the student is being introduced to it. (p.86)

The implication here is that if ideas and beliefs about science are communicated by the teacher either intentionally or unintentionally, then by definition they are reflected in science classroom interactions and, by the very nature of the teaching act, such communication will successfully result in pupils' uptake or awareness of those ideas. Hence the focus on awareness, rather than on ultimate consequences such as "achievement" or "attitude" is justified in this study.

In examining science teaching, Joseph Schwab (1962) refers to the transmission of various messages about the nature of science, about which a teacher may not be conscious, as "meta-lessons" while the unconscious assimilation of these ideas by pupils is referred to as "meta-learning" (p.45). Since one of the aims of this study is to identify the substance of ideas about science which are provided during science lessons, Schwab's concern about the kind of meta-messages left with pupils is useful to consider. Even though Schwab refers to the substance of secondary school science teaching, his concerns apply equally well for elementary school science.

Schwab recognizes the need for a scientifically informed student population. This means that the kind of science information and experience pupils acquire at elementary and secondary school becomes the base on which their future science understandings are built. Schwab is concerned that explanations about scientific phenomena may leave inaccurate impressions with pupils. For example, too often pupils acquire the idea that conceptual entities are "the same kind of thing" (p.46) as concrete, observable objects. Teachers often convey such "meta-lessons" without being aware of doing so. But what Schwab finds significant is that, over a period of time, the pupils assimilate these ideas, quite unconsciously. Schwab refers to these as "meta-learnings".

Schwab perceives the consequences of such "meta-lessons" as unfortunate, resulting in confusion and misunderstanding in the pupils' conception of the scientific enterprise, especially when the ideas conveyed to the pupils are not applicable to their own experiences.

> Consider the student who has never been taught to discriminate the conceptual from the physical. ...Since he does not know that some of the "things" taught him are not things but ideas, he cannot account for the sudden disappearance of all reference to them and he is still further confused by the new body of statements which refer to "things" of which he had learned nothing at all. (Schwab, 1962, p.47)

To avoid such effects, Schwab sees the need to provide pupils with clear explanations of the role played in science by observable things with a physical existence (such as tables and batteries). These should be distinguished from "idealizations" or conceptions which have been developed to organize data which would otherwise be difficult to explain (such as atoms and ions). Provision of such explanations would enable pupils to understand how science knowledge develops, grows, and changes.

The usefulness of Schwab's ideas is not in the long term consequences of meta-lessons about science to which pupils are exposed, but rather in the substance of those lessons and how they are conveyed to the pupils.

Toulmin (1960) discusses the need for contextual explanations or "logical asides" in order to avoid misunderstanding when scientific events are popularized for the layman. The same need for contextual explanations is found in elementary school discourse where the teacher controls the provision of science information and ideas about the nature of science. Without the logical asides, to which Toulmin refers, children may misinterpret how the science events or ideas are to be understood. Toulmin's argument is examined first as it applies to the non-scientific community and then it is extended to school children.

Toulmin differentiates between presenting scientific information to the layman, or those unschooled in science, and presenting scientific information to the scientific community. The language used for both groups may be the same ordinary or "everyday" language. However, only the scientific community understands the change or "shift" in meaning of this language as it applies to the science event. The layman does not. "The layman is not just ignorant of the theories of science, but also unequipped to understand the terms in which a scientist will naturally begin to explain them" (Toulmin, 1960, p.15). Then, the lay reader or listener is inevitably left with a confused impression of what is meant by the science information. To overcome such misunderstanding, Toulmin argues that the non-scientist must be made aware of the context in which the ordinary language is used.

To demonstrate his argument, Toulmin uses, as his major example, the discovery of and the explanation for the rectilinear propagation of light. Saying that "light travels in straight lines" is, for the scientist, a way of conceptualizing a particular phenomenon. But for the layman, this statement can be misleading unless appropriate qualifications are provided as to why the physicist talks about the optical phenomenon in this way. It is these qualifications or logical asides which, in the interest of brevity and simplicity, are most often eliminated when scientific ideas are popularized, or when they are presented, in ordinary language, to school children.

Toulmin uses a very brief, but simple analogy to show how similar misunderstandings may arise among children when they are read bed-time stories. Some children may easily recognize the kind of story being read, but unless they are told that some stories are true accounts, that some are make-believe, that there are no talking bears and so forth, they might develop inappropriate conceptions about their world. Such explanations are the "asides" to which Toulmin refers.

Toulmin's analysis can readily be related to science classroom interactions. Thus, the manner in which ideas about science are explained or presentations modified may be misunderstood by uninitiated elementary school pupils -- especially if the ideas are taken out of context or if lacking in logical asides. For example, suppose science lessons include such statements as: "the table is made of atoms", "this is a food chain", or "light travels in straight lines". Such comments are model statements appropriate for talking about scientific phenomena, but confusing for young pupils who cannot observe atoms, a food chain, or travelling light, nor can these be understood in the context of their personal experiences. What is needed, then, are explanations about the function of such statements in making sense out of the scientific events. Thus certain ideas about science may be communicated by the omission, as well as by the inclusion, of explanatory statements or rules. Since the teacher authorizes the communication of ideas, what pupils are permitted to say and do (or are prevented from saying or doing) during lesson interactions will also convey certain messages to them about the scientific enterprise.

Thus, the work of Green, Komisar, Schwab, and Toulmin provided theoretical ideas which justify the decision to investigate a particular aspect of teaching practice: The substance of the ideas about science which pupils become aware of during classroom activities and the manner in which teachers convey those ideas to their pupils.

The following sub-section now examines the practical justification for this choice of the view of the problem. An extract from an elementary science lesson shows how the theoretical ideas discussed above become evident in practice in the context of the lesson discourse.

### Practical Justification

Rational discussions with teachers about the nature and provision of ideas about science being conveyed during science lessons cannot rely solely on theoretical justification. Rather, in order to suggest changes in teaching practice, a supervisor or teacher educator must provide teachers with the actual evidence about issues in their science teaching performance. That such evidence can be found in the discourse of a science lesson is the focus of this sub-section and a practical justification for investigating this particular aspect of the problem.

An extract from the discourse of an observed (and recorded) grade four science lesson provides clues which suggest that certain ideas about science -- meta-lessons -- are being implicitly conveyed during the teaching act, that the pupils are becoming aware of these ideas, and that the absence of logical asides may leave the pupils with misunderstandings about a particular scientific phenomenon. The extract from the lesson is presented below and is followed by a brief analysis. (The analysis necessarily ignores the context of the lesson, and of the lessons which preceded or followed this one.)

> Teacher: Right. Positive ions. I'll put that word on here. (T writes ions on the board.) So the negative always tries to get to the positive...here we've got a negative charge in here (points to diagram on the overhead projector). It's just dying to get to the positive, but it can't jump through the air, 'cause the air won't carry the electricity. So how can it get from here to the positive part of the battery, Billy?
>
> Billy: Follows the wire. Goes where the wire goes.
>
> Teacher: Good. It follows the wire, through here, smash up here and over to the positive. Now if you wanted to stop the flow of electricity, what would you do?
>
> Pupil: Like, take the wire off. Off these.
>
> Teacher: Sure. Take it off here....What else could you do to the wire to stop the electricity from flowing through. Billy?
>
> Billy: We could cut it.
>
> Teacher: Sure. Just cut it. Now see the light switch we have in the wall here? Right behind here there's electricity and it's just dying to get up there, because up there we've all these positive ions and back here in the wall, we have a wire which is full of negative ions. It's gonna try and get there....

One idea communicated implicitly in this episode is that ions have a physical existence. Evidence for such a claim is found in the way ions are given the same logical status as other observables -- their presence is taken for granted. The "reality" of such entities is further complicated by the characteristics of "dying" and "jumping" that have been assigned to them. The meta-lesson thus presented by the teacher implies that use of anthropomorphism is acceptable when explaining scientific phenomena. Furthermore, the teacher may or may not be aware that such a view is being conveyed. However, because of the "auditor-uptake", repeated exposure to such ideas may inevitably influence pupils to accept these views as their own.

There is nothing in the extract from the science lesson, by way of (Schwab's) explanation or (Toulmin's) "logical asides" to indicate that the characteristics ascribed to ions could be understood differently (or even that they should be understood in a particular way). The omission of such clarification is an example of the concerns expressed by both Toulmin and Schwab regarding the kinds of messages pupils may receive.

As a science teacher educator and classroom supervisor, this investigator has observed other such science lessons which indicate that fundamental understandings -- meta-learnings -- about science are conveyed during a variety of science teaching activities. Moreover, the pupils' uptake of such ideas becomes evident in their comments during the lesson interactions. Most significantly, in terms of this study, no systematic device is available, to practitioners with similar responsibilities, for characterizing those understandings and for identifying how they are being communicated to the pupils. Consequently, there is no means for systematizing the actual evidence of classroom teaching in order to discuss rational changes in this particular aspect of science teaching practice. Such discussions would help teachers to make clear choices about the nature and the provision of the scientific ideas to be conveyed to their pupils, and would help supervisors rationalize discussion of classroom dialogue.

## Significance of the Study

The significance of this study is derived mainly from an immediate practical concern that is perceived by this investigator and others in the field of science education. That concern is in understanding both the nature of the science ideas being conveyed to children by teachers and the manner in which this occurs during elementary school science lessons.

Observation of classroom interaction appears to suggest that pupils are becoming aware of conflicting ideas about the nature of science. Moreover, it is believed that these ideas, communicated regularly and built up over time. form the basis of the pupils' future understanding about science. To realize that ideas about science are communicated to pupils is inadequate in the real world of the elementary classroom. It is important to determine what ideas children are exposed to before these become a part of their own belief system, and before these ideas can be measured as a product of science teaching. It is at the initial stage of the development of ideas about the nature of science that practitioners may rationally diagnose the consequences of further development of certain ideas. Moreover, in order to explore modifications to science teaching practice, teachers should have evidence of the manner in which the ideas about science are being transmitted. Hence, a focus on understanding the process of communicating ideas and beliefs about science rather than on the products of science teaching.

The analytical scheme, which is developed in this study, reveals, systematically, the nature and provision of the ideas about science that are transmitted in the discourse of science lessons. Such a tool should provide teachers, teacher educators, and supervisors with a coherent and rational means of identifying, interpreting and acting on the provision made for elementary pupils to become aware of these ideas.

## Limitations of the Study

The limitations of this study are of three types: the choice of the view of the problem, the limitation associated with the theoretical development of the analytical scheme, and the limitation regarding the assessment of clarity of the clues of the scheme.

View of the problem. This study is limited to elementary school lesson discourse, with the purpose of identifying the nature of science ideas being conveyed to pupils and the provision made by the teacher for those ideas. Justification for limiting the study to the nature and provision of ideas rather than outcomes or attitudes has been considered at length in the preceding sections of this chapter and will be explored further in Chapter II.

Moreover, there is no attempt to explore the ideas about science which children may acquire through television, books, or other sources of science information. Justification for this limitation stems from the professional role and responsibility of the investigator as well as other teacher educators and supervisors who are concerned with teacher performance and science teaching activities as these appear in classrooms.

Theoretical development. The theoretical development is limited by the categories of the scheme which include three views of science and three science activities. These are derived from the work of N.R. Hanson. No other meta-theorist's work is used to develop the analytical scheme although the writings of other philosophers of science are examined. Thus the theoretical base of the scheme is limited to the philosophical analyses which yielded the most useful categorizations for the particular context -- elementary school science. Justification for this limitation is developed more fully in Chapter III and limiting the scheme to three categories of science activities will be supported in detail in Chapter IV.

Assessment of clarity. No claim is made that the resulting analytical scheme can be readily applied to science lessons by practitioners. Assessment of the clarity of the scheme is limited to finding out if the clues of the scheme are recognizable in the discourse of a science lesson by persons other than the developer. The assessment, then, is an initial one and is the result of the application of the scheme to a science lesson by two independent judges. Although the judges were selected on the basis of their experience in science teaching, no attempt was made to train them in the use of the scheme. A detailed discussion of this assessment is found in Chapter VI.

This study, then, is limited to the derivation of an analytical scheme for the purpose of identifying the nature and provision of ideas about science conveyed in elementary school science lesson discourse.

## Summary

This study is concerned with the way in which elementary school science teaching can contribute to the development of children's conceptions of the nature of scientific thought and activity. The study is centered on analysis of classroom dialogue and science activity, and it involves the development of an analytical scheme for conceptualizing differing views of the nature of science. In this introductory chapter the argument of the study has been predicted, the view of the problem justified, and the methodology discussed. Research related to this study will now be considered in Chapter II.

# CHAPTER II

# RELATED RESEARCH

## Introduction

In Chapter I a decision was taken to examine classroom interaction during science lessons, rather than the product or outcome of science lessons, in order to study the nature and the provision of children's developing ideas about science. The review of related research which follows will further justify this selection of the view of the problem and will demonstrate the uniqueness of this study over other, similar investigations. Even though the studies reviewed are not useful for studying pupil-teacher interactions in the manner chosen by this investigator, any study which deals with the development of children's ideas about science can be considered as related research. Then, representative research from each of three groups -- product studies, process studies, and analytical studies -- will be examined briefly but not extensively analyzed.

Product studies are those which measure the outcomes of teaching usually in the form of the teacher's or the pupils' attitudes toward science, an understanding of science, or achievement which accrues from the science lessons. Process studies focus on the means or process by which instruction is carried out by recording and describing classroom interaction. Analytical studies represent a special type of process research in which teacher-pupil interactions or instructional materials are analyzed. These studies have been separated from the process group for reasons which will become clear later in the chapter. The present study will be noted as falling within this particular model for investigating children's developing ideas about science -- a process study which develops an analytical tool for identifying the kind of ideas about science to which children are being exposed.

## Product Studies

Product studies measure children's development of conceptions of science by studying the outcomes of teaching through the use of measuring scales or questionnaires. Such studies may include experimental treatment in which course changes or training procedures are carried out in the hope of improving the teacher's attitude and/or the pupils' attitude toward science, pupils' achievement in science, or their understanding of science.

### Attitude to Science

A positive attitude toward science shown by teachers and pupils is held as an important step toward improving both science teaching and pupils' achievement level in science. This has led to a search for "identifying factors that affect the skills and attitudes in science teaching" in order "to improve science teaching in elementary school" (Piper and Moore, 1977, p. 88). Examination of over 40 studies relating to teachers' and/or pupils' attitude to science reveals that such attitudes may become more positive as a result of appropriate courses, programmes, or training (Piper and Moore, 1977; ERIC search.[1] The superscript refers to notes found at the end of the chapter.) All of the studies refer to attitude in the sense of "appreciation for" and/or "desire to teach" science. Klopfer (1971) provides the most explicit explanation of the term attitude.

> This category of behaviors ventures into the affective domain, the domain that includes "objectives which emphasize a feeling tone, an emotion, or a degree of acceptance or rejection" (p. 576).

Moreover, Klopfer refers to this category of behaviour as a desirable "outcome of instruction".

Important, in terms of this study, is the way Klopfer pursues the concept of attitude while realizing that the "development of attitudes is generally a long-term proposition" (p. 577). He finds that "a student's attitudes and interests are always associated with cognitive elements" (p. 577) which include "scientific literacy" and the "student's orientation toward some significant philosophical aspects of science" (p. 579). Klopfer, then, perceives favourable attitude to science as complementing the view of science gained in the teaching-learning process.

It seems reasonable to assume, then, that "identifying factors that affect the skills and attitudes in science teaching" require initial recognition of the "significant philosophical aspects" of science which are being communicated and which would subsequently influence the attitudes toward science held by pupils. Identifying such ideas, implicit in what Klopfer terms "orientation" to science, could explain not only why, but how certain attitudes are acquired.

## Achievement in Science

Although the studies reviewed by Piper and Moore suggest that attitude toward science may change as a consequence of teacher training or courses, such additional courses are not necessarily followed by increased pupil achievement. A study by Wright and Nuthall (1970) is an example of an attempt to identify short-term (as opposed to long-term) effects of teaching behaviour on elementary school pupils' performance on an achievement test and on a Nature/Science Concepts Test. Although the teaching was carefully controlled and content of lessons selected, it was found that teaching behaviours "did not show a positive relationship with achievement" but "they may well have been positively related to other long-term cognitive objectives" (p. 489).

Hough and Piper (1982) studied the relationship between pupils' attitude to science and their achievement in science. In their study, the teaching was also controlled by the provision of detailed instructions to insure consistency in teaching practice. Furthermore, the use of residualized gain scores, rather than simple gain scores, appeared to remove the effects of individual differences among the pupils. With these research procedures, Hough and Piper found a relationship between the pupils' attitude toward science and their achievement in science.

More important, in terms of influencing teaching practice, achievement studies require the passage of time in order for the consequences of teacher training, or altered teaching behaviour, to become evident in pupil achievement. Practitioners, however, must have an immediate procedure for interpreting teaching-learning situations.

The present study provides such immediacy in the form of a new set of lenses for looking at the teaching act. The development of a scheme to systematically characterize the kinds of ideas about science which are being conveyed by teaching behaviour may contribute to teacher and pupil attitudes and, in the long term, to pupil achievement.

## Understanding Science

Other studies, in which the research purpose is to determine the teacher's or pupil's attitude towards and understanding of the nature of science, use a variety of rating scales or tests. The most frequently used Test on Understanding Science (TOUS) follows the format of multiple choice statements under three areas and eight themes (Cooley and Klopfer, 1963). All statements relate to understandings about science which the developers believe are consistent with the goals of science teaching in secondary school.

Investigators have continued to use the TOUS scale to measure understanding of the nature of science or changes in such understanding (Klopfer and Cooley, 1963; Schmidt, 1968; Lavach, 1969; Mackay, 1971; Fraser, 1978) and were joined by others who designed instruments specifically for their own studies (Kimball, 1967-68, NOSS; Welch and Pella, 1968, SPI; Hillis, 1975, VS; Billeh and Hasan, 1975, NOST).[2] All followed a similar pattern of research in which secondary students and/or teachers completed an appropriate questionnaire which was then empirically analyzed. Of this group, only Fraser adapted the TOUS scale for use with upper elementary and junior high school pupils. The findings of these studies have been interpreted to suggest that attitudes and understandings of the nature of science can be influenced by the provision of appropriate courses or strategies (similar to the results of the previously mentioned attitude and achievement studies). The assumption here, again, is that "courses" may improve (or correct) the understandings teachers hold about science and thereby increase their pupils' understanding -- eventually.

In spite of the value of such research into pupils' understanding of science, the studies do not indicate what provision is made for pupils to become aware of these understandings. The present study exposes this kind of information making it possible to diagnose science instruction and to discuss modifications to practice.

## Process Studies

Process studies include those investigations which usually involve the use of various observation instruments to describe and record the frequency of classroom events and utterances -- the transactions of the teaching act. An assumption of these studies is that noting (and changing) the behaviours of teachers may subsequently influence pupil behaviour, attitude, and achievement. A few examples of such studies are briefly reviewed since these represent an alternate way of viewing the means by which children develop views of science. This study may also be considered a process study; however, the manner in which classroom interaction is examined and the focus of the investigation, on the substance and provision of ideas which make up that interaction, is quite distinct. These differences will be noted later in this chapter and will become more evident as the discussion of this study proceeds.

An extensive review of research on teaching carried out by Dunkin and Biddle (1974) illustrates the literally hundreds of attempts by investigators to carry out "systematic observation of teaching in classrooms" (p. 3), much of which is directed to science teaching. In order to examine the process of classroom interaction, many of the instruments which have been developed are variations of the Flanders Interaction Analysis category system. Such scales are used to categorize teaching behaviour according to type and frequency of teacher-pupil utterances.

Parakh (1969) developed a variation of Flanders' instrument in the form of a 17 dimension category system in order to achieve a more detailed description and classification of interaction in high school biology classes. However, the interactions described included affective indicators (such as jokes and reprimands); solicitations and provision of information by the teacher and pupils; and classroom procedures. Such examinations of teaching behaviours are meant to provide clues for improvement in teaching practice and eventually in student learning. A study by Wright and Nuthall (1970) employed an observation form with 28 variables under five categories (closely resembling Flanders' categories). This work has been examined as representative of a product study; however, it will be recalled that Wright and Nuthall did not find a relationship between the frequency and type of teacher behaviour and pupil achievement.

In an effort to obtain more comprehensive information about classroom interactions during high school biology lessons, Tamir

(1981) used an observation instrument with categories borrowed from eight existing scales (one of which was Parakh's scale). The purpose of the study (among others) was to compare the interactions during sample biology classes. To do so, classroom interactions were timed. The nature of teaching was identified as practical or theoretical, concrete or abstract (for example). Questions were identified by number and type. Instructional technique was timed and identified as asking or answering questions, demonstrating, or summing up. This observation instrument, applied to the interactions, is not useful for determining what ideas about science pupils are exposed to during the biology or any other science lessons.

More important, in terms of this study, there is a substantive difference between the development and use of the observation scales in these process studies and in the present investigation. Current observation scales do not come to grips with identifying or describing the _nature_ of the messages -- the meta-learnings -- about science which are being conveyed by the classroom behaviours. Consequently, they are not useful for studying the problem of children's developing conceptions of science as perceived and selected by this investigator.

## Analytical Studies

Analytical studies are a distinct type of process research which can be distinguished from the others by the way in which the classroom interactions are studied. There is an attempt to analyze (rather than count or describe) teacher-pupil interactions or the teachers' and pupils' views of the nature of science. Such analysis may depend on philosophy of science for the derivation of ideas about science.

The review below includes early efforts to analyze children's ideas about science. This is followed by two studies in which philosophy of science is related to the education of science teachers. Major studies are then reviewed in which analytical tools are developed from philosophical analysis for categorizing secondary science classroom interactions and instructional material. The present investigation is an example of this kind of study but with a distinct difference both in the development of the analytical tool and in the purpose of the tool or scheme for investigating science practice in the elementary school.

## Early Analysis of Childrens' Views

Oakes (1942) and Haupt (1948, 1949, 1952) carried out some of the earliest attempts to analyze the comments children (from K, grade 2, 4, 5) make about natural phenomena. Oakes classified the nature of childrens' explanations of phenomena using their individually recorded answers to questions which were drawn from the work of Piaget. The responses were assigned to three categories: Physical or Materialistic, Non-Physical or Non-Materialistic, and Failure to Explain. Oakes found that childrens' thinking is mostly Physical and he suggested that his findings should be considered when planning classroom procedures and science curricula.

Haupt carried out three studies to classify and interpret the remarks made by elementary school children (grade 1-7) about the moon, hot and cold, and magnetism. Using observational and interview techniques to gather his data, he noted the degree of reasoning and understanding as well as the complexity of childrens' statements.

The studies by Oakes and Haupt do not address the problem of how the children become aware of their understandings, or of how they think about science as an enterprise. Without this information, it is not realistic to expect practitioners to plan science lessons differently or to modify their teaching in the light of conscious choices regarding the communication of ideas about science.

## Analyzing Views of Science

Robinson (1968) made an early and significant effort to relate philosophy of science to science education by analyzing the views of the nature of science held by six "scientist-philosophers": Margenau, Frank, Bridgman, Woodger, Beckner, and Gerard. As a result of his analysis, Robinson derived a "structure of science" in the form of a list of appropriate "understandings" for teachers and teacher candidates to acquire in order to achieve scientific literacy. The implication (as in the product studies) is that changes in the teachers' understanding of science will be transferred to their pupils. The list of understandings, then, serves as a guide to a shift of emphasis in science curriculum revision.

> A shift in perspective, especially a shift in the philosophical perspective with which a teacher interprets natural phenomena to students, requires significant shifts in the patterns of science education. (p.112)

Robinson's "shift in perspective" makes sense. However, he does not address the question of finding out what philosophical perspectives about natural phenomena are being conveyed in science education nor how such ideas are provided for -- especially in the elementary school where children become aware of scientific interpretations at an early age.

Based on the assumption that teachers and pupils hold "inadequate conceptions of science", Ogunniyi (1982) developed a 64 statement instrument (LOS) to measure the influence of a science methods course on the concept of the Language of Science (LOS) held by preservice (secondary) teachers. In relation to this review of research, the LOS instrument was derived from the views of the language of science held by seven philosophers of science -- an application of philosophy of science to science instruction. As in the previous studies, the instrument does not resolve the problem of how these messages about the language of science are being transmitted to pupils in elementary classrooms.

## Philosophical Analysis

The process studies reviewed above utilize concepts drawn mainly from the natural and behavioural sciences. However, a number of investigators, recognizing the needs of practitioners, have turned to philosophical analysis to develop procedures for analyzing secondary school science lessons as well as science textbooks. This is in keeping with an alternate research approach advanced by Roberts and Russell (1975) in which they argue that philosophical analysis can provide the theoretical base for "understanding issues important to education and to science" (p. 115). The following studies are more closely related to the present investigation both in style of research and in relevance to teaching practice. However, differences are found in the context and conceptualization of the study and in the development of an analytical scheme.

Two studies which focus on the application of philosophical analysis to science instruction were carried out by Munby. In 1969 he developed an analytical scheme which is derived from Scheffler's three models of teaching (1965): the impression model, the insight model, and the rule model. Munby applied his scheme to transcriptions of science lessons in order to distinguish the style of teaching consistent with characteristics found in the models. In the second study (1973), Munby developed a two-category analytical scheme which he applied to science lesson discourse. The first category identifies two contrasting views of the nature of science, instrumentalism and realism, derived from the work of Nagel (1961). The second category of Munby's scheme identifies the provision made by teachers for their students to develop intellectual dependence or intellectual independence. The theoretical perspectives for this category are derived from epistemology and philosophical analysis of teaching.

Kilbourn carried out two studies to demonstrate the value of analyzing science teaching material. The scheme he developed in 1970 was derived from epistemological perspectives and is useful for examining the knowledge claims about science present in science textbooks. In applying the scheme to parts of a secondary biology textbook, Kilbourn identified the difficulties students may encounter in understanding selected information in the text readings. In 1974, Kilbourn applied Pepper's conception of World Hypotheses (1942) to the development of an analytical scheme. The scheme is useful for identifying the notions about world views which are conveyed through science teaching materials. To demonstrate the scope of his scheme, Kilbourn applied it to various types of news and journal articles as well as to a biology textbook.

The educational context addressed by Russell (1976) differs somewhat from that of the other researchers mentioned. He investigated the provision made in a teacher education programme for prospective science teachers to develop views of science and a concept of teaching. Russell's multiple category analytical scheme is derived from interpretations of the nature of science by Körner, Carnap, Popper, and Kuhn. The theoretical perspectives for the concept of teaching are derived from various writings. Russell applied the scheme to teacher education textbook passages in order to analyze the argument patterns which express, implicitly and explicitly, why and how science should be taught in secondary school.

In each of the above studies an analytical scheme is developed directly from theoretical perspectives found in philosophical analysis. The scheme is then applied to science teaching or teaching materials. The applications demonstrate the power of such schemes in identifying and understanding specific aspects of secondary science teaching practice. These studies may be similar to this dissertation in relevance to teaching practice and in research style; however, the present study carries this line of educational research a step forward to the development of a scheme for analyzing significant views of science in elementary school discourse. More important, the clues of the analytical scheme are derived from the lore of the elementary classroom as well as from philosophical analysis. Rather than by linear development from theoretical perspectives to a scheme to application in practice, the scheme for this study is developed by reflexive analysis of both classroom events and theoretical perspectives for understanding science education realities in elementary school. The chapters which follow demonstrate how this is accomplished.

## Summary

The above review demonstrates that extensive research efforts have been applied to science teaching in an attempt to understand and improve instruction. Studies based on a cause-effect relationship between teaching and learning, investigated the ways in which teaching strategies, science courses, or programmes affect pupil attitudes toward science, and subsequently their achievement. However, this investigator perceives pupil learning, over which the teacher has little control, to be separate from pupil awareness, over which the teacher does have an effect. Since the acts of teaching science result in pupil awareness of certain notions about the scientific enterprise, then it is legitimate to examine evidence of such awareness provided for during science lessons.

A large number of schemes for observing classroom interactions have provided general, but useful, categories for describing the process of teaching. However, this study is concerned with detecting and categorizing ideas about the nature of science which are transmitted to pupils as "meta-learnings" during the process of teaching in the elementary school. No category scheme for doing so is presently available.

The analytical schemes developed directly from philosophical analysis, and reviewed above, are not applicable to the context of an elementary school science classroom where the experience and understanding of teachers and pupils has not reached the sophistication of secondary school pupils or their teachers. A scheme used to analyze elementary school discourse must be more closely related to the contextual realities of the elementary level of science language and instruction. A reflexive development of an analytical scheme, then, enables this investigator to relate theory more closely to elementary school practice. The resulting scheme is meant to identify the ideas about science which are communicated to pupils, to detect the provision made for the pupils to become aware of those ideas, and to interpret the evidence of pupils' awareness or uptake of these ideas.

The chapter which follows examines the theoretical perspectives for understanding scientific ideas since these constitute the substantive elements of the scheme for characterizing elementary classroom discourse and science activities.

Notes

1. An ERIC search was carried out in 1978 using the following descriptors: scientific literacy, concepts, principles, attitudes, enterprise -- each in combination with elementary school teachers. This set revealed 16 citations. Elementary school teachers combined with teacher attitude revealed 30 citations. Elementary school students combined with scientific attitude, enterprise, literacy, methodology revealed four citations. A search, repeated in 1981 with elementary science teachers, elementary science, and scientific literacy as descriptors, revealed four citations.

2. The rating instruments are: Nature of Science Scale (NOSS); Views of Science (VS); Nature of Science Test (NOST); Science Process Inventory (SPI).

# CHAPTER III

# THEORETICAL CONCEPTIONS OF SCIENCE

## Introduction

The analytical scheme developed in this study incorporates clues for identifying the substance of different ideas about the nature of science, in a manner in which these might conceivably appear in the discourse of elementary school science lessons. This chapter and the next one deal with each of those two matters respectively.

Identifying and categorizing the substance of ideas about science requires a theoretical base from which to draw the characterizations. Various sources of such ideas are available in the literature of philosophy of science and, in particular, in the analysis of scientific terms and methods of acquiring scientific knowledge. Since the context of this study is elementary school, philosophers are chosen whose work can be seen to contribute effectively to distinguishing ideas about the nature of science at this level of classroom discourse. But further, philosophers are chosen who have come to grips with different conceptions of the nature of science, since an important feature of the problem of this study is the intuitive sense that conflicting messages about the nature of science are manifest in the classroom.

In the present chapter, the work of Ernest Nagel, Rom Harré, and Norwood Russell Hanson is examined. All three of these philosophers analyze the scientific enterprise from more than a single point of view which could provide useful characterizations.[1] The investigator argues that the distinctions between scientific ideas expressed by Nagel (1961) and by Harré (1976) are not appropriate for the level and context of elementary school. Hence the ideas of those philosophers are reviewed briefly, but are not subsequently incorporated into the theoretical perspective underlying the analytical scheme.

The manner in which Hanson conceptualizes science and extends his analysis to the activities of scientists is found to be unusually appropriate for distinguishing ideas about science in elementary classrooms. Hence the theoretical basis of the analytical scheme is derived from his work (1965, 1969, 1971). Hanson's views, then, will constitute the major discussion of this chapter.

## Nagel's View of Science

Nagel (1961, ch. 1,2,5,6) considers the goal of science to be the organization and classification of knowledge -- based on the principle of explanation. Scientific explanations are controlled by evidence and as such fall into distinct, logical patterns. The language of explanation then, cannot be vague or indiscriminate, but must be specific, in order to convey the logic by which unfamiliar phenomena are made, as much as possible, understandable.

Nagel considers scientific explanation to be achieved through the help of assumptions or theories, which he finds are much more comprehensive than experimental laws. Although it is difficult to draw sharp distinctions between laws and theories, Nagel does find major differences which influence the kind of explanations used. For example, experimental laws express the relations between "observable" things, which can be confirmed by direct evidence or experiment.

On the other hand, theories refer to a set of assumptions which are not apparently observable. Theories cannot be put to direct experimental test and so cannot be confirmed by observations or experiments. If a theory is to be used as an explanatory device, then it must be linked to observable materials. It is this requirement which connects theoretical notions, such as electrons, to what is observed experimentally. Experimental laws are then deduced from theoretical assumptions and since the law is based on observable evidence, it can survive when the theory is no longer viable. Since theories are sets of assumptions, the postulates which are included in the theories assert nothing more than the terms defined by the theory. According to Nagel, such postulates may be embedded in models or analogies which are useful in explaining or interpreting the unfamiliar in terms of the familiar.

Although Nagel supports an instrumentalist view of the status of theories, he examines two other views as well since the characteristics of each determine how scientific explanation is perceived. An instrumentalist view is concerned with the function of theory in scientific inquiry and considers the theory to be a useful instrument for analyzing phenomena of "gross experience" -- with some theories being more useful or superior to others in their explanatory power, but not considered to be true or false. This view causes some confusion regarding the status of scientific objects (such as atoms). Since a theory is a "leading principle" or a technique for establishing inferences based on methods of representing phenomena, then it is irrelevant to say that entities have a physical existence.

Such "objects" function only as conceptual links in the representation. Then again, there are some physicists who consider such objects to be as real as "our hands and feet" because of observable experimental evidence. The problem for the scientist lies in judging the criteria that are associated with physical reality.

For a holder of the realist view of scientific theory, a lack of evidence and the confusion in establishing criteria for physical existence is not an adequate reason for deciding against the existence of postulated entities. If a theory is well regarded and well established by "competent evidence" then the postulates within the theory do have or are designated to have a "kind" of existence. Theories are considered to be true or false statements in their explanatory power. If experimental evidence indicates an incompatibility between what a theory asserts and what is observed, then the discrepancy is considered to be due to experimental error.

A descriptive view of theories is based on a historical idea that theories cannot explain, they can only describe the relations between events. The influence of the phenomenalist theory of knowledge affects this view in that theoretical statements can be translated into statements about observable events, or "gross experiences". Thus theories can be characterized as true or false, although most often with the preface "probably". Scientific objects, then, also take on a physical existence, though the terms are considered to be "shorthand notations for a complex of observable events" (Nagel, 1961, p.118).

In discussing the different views of scientific explanation, Nagel considers philosophical issues which are inappropriate for an investigation of elementary school science dialogue. Although explanations are given and received during elementary science lessons, these are usually associated with science activity -- the doing of science -- rather than in terms of scientific theory. Moreover, one of the focuses of the study is to identify the manner in which a teacher communicates science ideas. Since Nagel favours an instrumentalist view, his analysis does not include the kind of balanced distinctions needed for making these identifications. Consequently, Nagel's views are not incorporated into the development of the analytical scheme.

## Harré's View of Science

Harré (1976) considers two views of science in terms of the process of reasoning, the status of scientific knowledge, and metaphysical theories. He fully supports a realist view, and he finds a positivist view (associated with phenomenalism) to be unacceptable.

To Harré, the world is perceived as full of "things" (rather than sensations) and these things or objects assume an identity or existence even when they are not directly observed or detected. This is made possible by the development of a system of concepts and by the development and utilization of appropriate instruments. Harré makes reference to the virus, a hypothetical entity, not observable until the development of the electron microscope gave it a reality. Other instruments such as the electroscope or the compass serve to detect the effects of some entity without direct sensory contact.

Thus, some, but not all, hypothetical entities are considered real if only by extension or by detection of their effects.

The positivist view on the other hand, does not consider hypothetical entities to be real or candidates for existence. Since what cannot be sensed is not there, scientific knowledge concerns that which is both observable and manipulable. Sense experiences which can be objectively described, constitute empirical knowledge.

For Harré (1976), theories function to explain not to describe reality. They "refer to the causal mechanisms at work in the production of phenomena" (p.61). This (realist) view assumes an intellectual activity and a knowledge of other theories so that appropriate statements and analogies can be utilized in the process of scientific explanation. Harré refers to two scientific concepts and their analogues to advance his point. The force/effort analogy is an example of a facile description -- not an explanation -- of the mechanism of mechanics. The virus/bacteria analogy not only describes the nature of viral activity, but includes the cause or the mechanism which produces the event, in this case the disease. The latter is a clear example of scientific explanation.

In arguing against the positivist view, Harré declares that the sole aim of theory according to this view is to "provide a basis for the deduction of laws" (p.54) and, as an extension of this, that explanations are achieved by deduction. Thus an event is explained if a description of that event can be deduced from a "covering law". Theoretical concepts included in theories are utilized solely as "logical devices" and have no independent status or empirical meaning.

In an earlier work, Harré (1970) refers to a third "tradition in Philosophy of Science" (p.1), conventionalism. However, he does not identify how this view of science differs from the others. He does claim that positivism and conventionalism utilize a common process of reasoning -- deduction -- to account for scientific problems. To Harré this form of reasoning is one of many but not as useful as the realist view of theory development and explanation, which is more closely associated with the way scientific inquiry proceeds.

Harré examines two views of science, but he expresses a distinct preference for a realist view, thus presenting an unbalanced analysis. Moreover, the level of theoretical understanding associated with his philosophical ideas is not found in the elementary school classroom. Additionally, Harré's analyses do not provide clear characterizations which would be useful in identifying the substance of scientific ideas or the manner in which these are conveyed during elementary science lessons. Harré's views, then, do not contribute to the development of the analytical scheme.

## Hanson's Conception of Science

Norwood Russell Hanson considers the goal of science and thus the activities of scientists to be the search for theoretical understanding about puzzling phenomena or events. Such understanding assumes that scientists have a comprehensive body of theory and experience from which to draw which would lend support and direction to their investigations and result in connections being made between observations of phenomena and prior knowledge about the phenomena or some aspects related to them. Most important, scientific understandings are transmitted or explained to others through the use of an "ordinary language" mode, the "theory-laden" terms of which mark the difference between descriptive reports of "sense-datum" experiences and investigations conceptualized in the context of what is known.

Hanson (1971) claims that this "attainment of theoretical understanding, knowledge" (p.8), has been hampered by the philosophical extremes of formless sensationalism on the one hand, and the rules of formless thought on the other. He tries to resolve the conceptual tension caused by these views through a "'via media'" or a "middle of the channel" synthesis (p.2). In analyzing the varied activities of scientists from these philosophical points of view, he characterizes each activity in a way which identifies them on a map of scientific and philosophical thought.

Hanson (1971) analyzes more than the three science activities analyzed below. However, it is appropriate for the context of this study to select from his analysis the three commonplace scientific activities (observation, experiment, explanation) which are plausible as the total range of elementary school science activities. (This matter is dealt with in detail in Chapter IV.) Hanson shows how each commonplace may be analyzed from three philosophical points of view. What follows, then, is a review of Hanson's philosophical conceptions for each of three science activities -- observation, experiment, and explanation -- from a sensationalist, a formalist, and a via media point of view.

## A Sensationalist View of Science

Observation. Observations based on random sensory experiences become the modus operandi of sensationalist thought. The observer, as a mere receptor of retinal signals, "sees" what is in front of his eyes with some efficiency and reliability, unadulterated by inference, intellect or knowledge. The assumption here is that such "dust bowl empiricism" may provide a normal observer with enough "scientifically valuable observations" (1971, p.4) to generate a theoretical understanding of the otherwise unfamiliar event or phenomenon being observed.

When normal vision proves to be inadequate to the task of gathering adequate information, various instruments of observation serve to extend the visual acuteness of the observer and provide more data for consideration. Furthermore, the truth or falseness of scientific events also arise from such direct encounters or from memory of sensory or pictorial experiences. The knowledge thus acquired is transmitted to others through the use of visually descriptive language and statements of matters of fact.

Experiment. Experimental inquiry which is carried out with a "completely open and unbiased mind" (Hanson, 1969, p.249) is the essence of sensationalist thought. The assumption here is that successful experimental activity is carefully implemented without the benefit of exisiting or prior knowledge about the phenomenon being investigated and with no preconceptions or assumptions about the kind of results to expect. Rather, as much data as possible should be gathered. Such data is important as it contributes to the generation of new scientific theories or corrects existing theoretical understandings about the problem under investigation.

Hanson considers such phenomenal inquiry to be insignificant in that some information of value may be overlooked in the search for "'something more'" (1971, p.26) while other bits and pieces of information may have little or no connection with the problem under investigation. Nonetheless, scientists, so engaged, consider these contradictions to be surpassed by the mass of evidence exposed by accurately executed inquiry, using precision instruments. Collecting such "matters of fact" becomes the goal of the experiment.

Explanation. According to the sensationalist view, explanation of a phenomenon involves understanding, or making sense out of an event through "old-fashioned familiarity" (Hanson, 1971, p.43). There is no need for a theoretical argument or prior scientific knowledge about the phenomenon to guide the understanding. Rather, making sense out of a problem follows from the sense-data information collected during random experiences with the reality of the problem. Such explanations are considered to be sufficiently important to generate a new theory or to alter existing theoretical understanding about the particular event.

Scientific events, in this view, are explained to others through the use of simple language involving descriptions of matters of fact or by computation of the results of experimental inquiry. In fact, the phenomenal terms used, such as red, ball, big, small, are considered to be theory-independent since they are visible bits of data which do not rely on any prior scientific knowledge and are readily understood in the context of sensationalist explanation.

## A Formalist View of Science

Observation. According to the formalist view of scientific observation, prior theoretical conceptions have greater importance than the data collected through retinal sensations, so that the (results of) observations are significant in so far as they confirm what is already known. The theoretical structure, then, is the basis upon which ideal, controlled studies are carried out with the resulting observations serving as the variables for mathematical calculations. This means that observations (even those derived from "extending" instruments) which deviate from the "ideal" or expected conditions, are considered to be inadequate or else the tools of observation are considered to be insensitive to the task. Such observations may be "reshaped" or "corrected" to fit the a priori theoretical framework.

Experiment. In carrying out experimental inquiry, the investigator enters "the laboratory with preconceptions about what must be the outcome of (the) experiment" (Hanson, 1969, p.249). This assumes that preexisting knowledge about the phenomenon being investigated will determine the direction and form of the experimental inquiry, and only a recognized theoretical argument can lead the experimenter to the relevant data that is expected. This type of inquiry is frequently evident in controlled experiments, under "ideal" or "pure" conditions. Should the results contradict expectations, then the experiment is considered to be unsuccessful and must be redesigned and/or repeated. Further contradictions of theoretical assumptions are considered to be anomalous. The prevailing theory would not be discarded, rather the anomaly is considered to be an unusual case within the theoretical framework. The rightness of the experiment, then, results in a demonstration or a corroboration of what is already known about a phenomenon (Hanson, 1971, p.27).

Explanation. Formalist thought looks to explanation as a set of rules for making sense out of scientific phenomena. Such explanations are rigidly reasoned to fit an a priori theoretical framework without the need for further experience or familiarity with the phenomenon being explained. Furthermore, theoretical preconceptions provide for predictions of future states of affairs and are therefore considered to be "the instrument through which explanations of those future states must also proceed" (Hanson, 1971, p.42). Since "predicting x is explaining it before it has actually happened" (1971, p.43), explanations are forced to conform with existing understanding irrespective of experiential findings.

Anomalies, then, cannot be dealt with easily. These are accommodated as special cases or special conditions of the theoretical premise, otherwise the existing framework would have to be revised or reexamined, which is not possible within formalist thinking.

## A Via Media View of Science

Observation. Hanson believes that a middle or via media view of scientific observations involves gathering information about the world through seeing events as those of a certain kind because they are filtered through a background of knowledge and experience. Even if the observer is not certain about what he sees, there is a "perceptual framework" or "set" behind the retinal sensations which gives meaning to that which is seen, enabling the observer to distinguish significant facts and anomalies from irrelevant data. Making such distinctions is a "theory-laden activity" (Hanson, 1971, p.5) which requires a theoretical understanding about the event or phenomenon observed and/or related events, as well as the context in which the observations are made.

When using scientific instruments to extend the power of the senses, the user must recognize the limitations of his tools and relate his observations to what is known about the phenomenon and the power of the instruments. "Being able to make sense of the sensors requires knowledge and theory - not simply more sense signals" (Hanson, 1971, p.5).

Hanson believes that observations made from this balanced point of view include a linguistic component which enables one to report on relevant observations using theory-laden terms intelligible to others, thereby adding to the accumulation of scientific knowledge. Without such association with prior knowledge, making observations (of any kind) would be mere "visual copying" of objects and would serve no purpose in the advancement of scientific understanding.

Experiment. Successful experimental inquiry according to this view, requires the recognition not only that a problem exists but also that "such a difficulty or problem (guides the) search for order among the facts. And...it is only the discovery of such an order... that will resolve the difficulty" (Hanson, 1969, p.222). The experimenter, then, must have a background of theoretical knowledge about the subject being investigated and experience in experimental procedures in order to design the inquiry relative to a particular conceptual framework and to recognize important evidence which results from the inquiry.

Thus, each experimental inquiry and the results derived are a test of the "whole body of relevant knowledge" (Hanson, 1969, p.254), the experimental design, and the assumptions on which these are based.

Explanation. A satisfactory explanation of some event is possible only if that event can be set into a conceptual pattern with other, related events. Then, a background of knowledge about a scientific phenomenon is useful for making sense out of the information derived from inquiry, and experience with similar phenomena.

According to such a view, scientific explanations are expressed in theory-laden language. This assumes certain understandings about the meaning of the terms and the context in which they are used.

## Summary

In analyzing the structure of science, both Nagel and Harré emphasize the comprehensive role of theories and entities in the logical development of scientific explanation. The conceptions of these writers raise complex philosophical issues well beyond the conceptual understanding and science experience of elementary students. The issues are simply irrelevant to the context of this study.

Moreover, in terms of this study, the set of clues which make up a scheme for analyzing lesson discourse must be sufficiently comprehensive so that well-defined distinctions can be made of the views of science which are being conveyed in classroom events. Notwithstanding the fact that some of the concepts presented by Nagel and Harré do emerge in the dialogue of elementary lessons, the views of science are not clearly characterized by Nagel, while Harré considers only two views with a less than comprehensive analysis of one of these. Thus the views of these writers do not contribute directly to the development of the analytical scheme.

Hanson analyzes scientific inquiry from two polar views, sensationalism and formalism, which are discrete and distinguishable, as well as from a middle or balanced view. Furthermore, his analysis is done in terms of science activities, some of which are unquestionably encountered in elementary science lessons. By assigning separate characterizations to different activities, Hanson provides the kind of comprehensiveness which is useful for analyzing school discourse where a wide range of ideas about science are communicated.

Consequently, the philosophical positions of sensationalism, formalism, and via media are borrowed from Hanson to form the foundations of an analytical scheme, the purpose of which is to identify the ideas about science which are provided through school science activities. The chapter which follows presents a practical justification for choosing certain of the activities analyzed by Hanson, and examines Hanson's theoretical conceptions in the context of elementary school classroom practice.

Notes

1. Henry Margenau's ideas about science were also examined during the preparation of this study. His views about the development of constructs, during scientific activity, for the building of theoretical understanding are quite similar to Hanson's views about achieving theoretical understanding. However, Margenau does not present other that a single conception of science which does not provide the differentiation needed for the development of a clue structure for the analytical scheme.

# CHAPTER IV

# PERSPECTIVES OF SCIENCE AND REALITIES OF PRACTICE

## Introduction

Closely tied to characterizing the substance of the ideas being conveyed during elementary science lessons is the matter of identifying the provision made for pupils to become aware of those ideas and the evidence of that awareness. In Chapter I it was argued that the teaching act includes a variety of activities which involve the teacher in transmitting ideas about science and which involve pupils in becoming aware of those ideas. The classroom activities, together with associated discourse, are seen as the vehicle by which ideas are provided about the nature of science in the course of ordinary science lessons.

The discussion which follows identifies three such school science activities which seem (initially) plausible for this study since they are typically perceived in elementary school lessons. The discussion indicates the practical basis on which that representative selection was made. Hanson's extended analysis of the same three science activities, from three philosophical points of view, has already been examined. Since his analysis concerns the activities of scientists, this investigator first discusses the divergence in experience and understanding between scientists and children, before attempting to apply Hanson's scientific perspectives to the realities of elementary school practice.

## Classroom Science Activities

A practical justification for the selection of certain science activities, but not others, is attributed to this investigator's experience in science education and in supervision of classroom teaching. Among the elementary science activities usually observed during school visits, three predominate: observation, experiment, and explanation. Since various other activities, also evident during lessons, may be grouped readily within these major commonplaces, it seems reasonable to select these three activities as the initial focus in analyzing science lessons. However, to be more sure that this claim is justified, science textbooks for elementary teachers and selected elementary science programmes have been examined to determine the importance given to these activities in elementary science teaching.

Many science textbooks are available for elementary school teachers. Three have been selected for this review since they differ considerably in structure and in approach to teaching science.[1] Yet, each gives prominence to the three science activities mentioned or to activities which can be grouped within these commonplaces.

George Ivany (1975), in his textbook for teachers, asserts that explanation of natural phenomena is an important and influential teaching activity. He points out that the manner in which questions are answered and information presented leaves pupils with certain implications about science, and consequently that all forms of explanation must be handled carefully (p.24-26). Throughout the book, Ivany encourages the use of observation and measurement since, in his judgement, these represent an empirical base and a necessary condition for inquiry. Ivany refers to various forms of experiences, (rather than experiments) such as classifying, gathering of data and a general discovery-oriented atmosphere.

In the third edition of their textbook, Carin and Sund (1980) stress the need for an investigative approach to elementary science which they consider to include the use of measuring devices. The recommended activities require pupils to make observations and carry out either unstructured investigations or experimental activities, depending on their cognitive level. Among the other activities recommended by Carin and Sund are formulating hypotheses, outlining procedures to test the hypotheses, and inferring.

Among the selected methods of teaching science, Victor (1975) finds experiments and demonstrations "ideal techniques for problem solving" -- a main objective in science education. In solving problems, "children are learning to think critically and creatively, and to develop proficiency in the key operations of science and the scientist" (p.62). According to Victor, such science activity involves making and classifying observations, examining evidence, referring to background knowledge, hypothesizing and drawing conclusions.

An examination of elementary science programmes reveals that similar emphasis has been adopted by major curriculum developers. The Science Curriculum Improvement Study (SCIS, Karplus and Lawson, 1974) stresses that the development of scientific literacy by pupils is attained through experiments using a variety of tools, through observation and manipulation of natural phenomena, and through discussion and explanation of science experiences. Similar activities in science instruction may be found in Elementary Science Study (ESS, Aho et al., 1974), and STEM Science (Rockcastle et al., 1977) with differing emphasis. The Science...A Process Approach (SAPA) instructional programme (AAAS, 1975) is based on process oriented activities such as observing, classifying, measuring, communicating, predicting, inferring, followed by other processes such as formulating hypotheses and experimenting. All of these activities are given prominence in the SAPA programme.

The three textbooks and these four science programmes illustrate that the three science activities or commonplaces selected are considered to be important by other educators. The "remaining" suggested activities, which did not appear to "fit" these commonplaces, can be regrouped within these three categories. The activities of classifying and gathering of data recommended by Ivany are an integral aspect of observational and experimental activities. The use of experiments and demonstrations, stressed by Victor, serve an important role in stimulating classroom communication which leads to explanation of observations made. And, the process activities of SAPA may be subsumed readily by the three suggested commonplaces. Making inferences is part of attempting to explain phenomena, and formulating and testing hypotheses are processes based on inferring. The latter activities, including measurement, recommended by SAPA and by Carin and Sund, can generally be associated with experimental inquiry.

Thus only three commonplaces of scientific activity, as selected above, will define the total range of activities for the analysis. Observation, as the basis of all other science experiences, refers to any classroom activity in which pupils use their senses while handling materials. This includes the use of sense-extending or observation-enhancing instruments such as lenses or microscopes. Experimentation refers to any type of "investigation" in science. This could mean a whole range of activities from simple mixing of substances to planning and executing a controlled experiment. Explanation involves both teacher and pupils in various forms of communication about events which are experienced, in an attempt to understand them. As will be discussed later, the language used in explanation, evident by the teacher's statements and the pupils' comments, becomes an important criterion for determining the view of science being conveyed during science lessons.

## Realities of the Classroom

The clues of a scheme for analyzing the discourse of elementary science lessons must be sufficiently comprehensive and clear to identify the wide range of ideas being communicated in school. Hanson's work provides this comprehensiveness, but his theoretical views of science and scientific activities are at an intellectual and experiential level far removed from that of school pupils. The point is illustrated by consideration of two of the commonplace activities of science: observation and explanation.

## What Children "See"

Hanson himself recognizes that the kind of observations carried out by children are different from those of a scientist. They (both) "see" the same scientific phenomena, but

> children are taught to be specially observant. They notice everything. Having in a way less knowledge and experience than we have had, they comment on things at random. Their visual interests are splayed far and wide instead of being organized as ours are... around a rather limited number of visual and intellectual focal points. (Hanson, 1969, p.152)

The scientist, on the other hand, ignores much visual data and makes observations on the basis of what is known about similar events, what is expected under certain circumstances and/or on the basis of the conditions under which the observations are made. Reports will be readily understood by others with similar experiences and prior understandings.

Even though it is easier for children to comment at random about their visual impressions and to talk about "what is in front of their noses", these encounters with reality are important influences on their understandings. In addition to this personal familiarity with concrete impressions, they have had other, vicarious, experiences and some prior knowledge (if only acquired through the process of growing and maturing) and they bring all of this background to bear on how they interpret their observations. Hence, one cannot assume that children "see" in a strict, phenomenological, retinal manner. Children inevitably view, talk about, or act on objects or events which they encounter by reflecting on their limited store of knowledge derived from personal contact with the same or similar events. Their understanding is also influenced by science experiences in school. In fact, Hanson considers one of the purposes of elementary science to be an avenue for providing pupils with new experiences into which later observations can be meaningfully assimilated. It is through the "pains of an education" (Hanson, 1969, p.152) that we (and children) learn to ignore certain "visual stimulus patterns" and recognize others as important.

Hanson (1969) illustrates this by referring to the "sense of floundering bewilderment" (p.166) felt by freshman students when confronted by their first biological tissue. Without prior knowledge about or experience with the "real" material, the students are unable to identify it or to distinguish what is significant about the tissue from what is unimportant. The demonstrator must provide students with a perceptual framework or "set" so that certain parts of the tissue stand out. At the same time, the students are expected to make as many unbiased observations as possible -- to see what is there as well as what is supposed to be there. Elementary school pupils may encounter the same kind of experience. Their perception and understanding about unfamiliar objects or events is influenced by the "set" of information and ideas conveyed by the teacher or derived from books, as well as gained through their own "unbiased observations."

## How Children "Explain"

To Hanson, an explanation is a theoretical exercise in accounting for events so that they are understood in the scientific community. This requires a body of knowledge and experience. In the elementary school, explanation of events also refers to "accounting for" whatever is observed or investigated, but without the benefit of the scientist's understanding. It is this difference which may create difficulty in analyzing lessons. There is a scientific distinction between explanations as making sense out of something and explanations which are descriptions of states of affairs.

In schools a variety of explanations can be expected in response to a "why" question: "Why did the cheese turn green?" "Because it was on the table all night." Or: "Why didn't you eat the cheese?" "Because it turned green." The responses here relate to states of affairs, what is obvious to the students through their sensory perceptions. These are not explanations in the Hansonian sense. Then again, an explanation may range all over the "map of thought" in response to "Explain the difference between the effect of soap and glycerine on water." There could be a theoretical explanation or a description of what is observable. The distinction is made not only by what is expected by the teacher but also by what is accepted as the explanation -- a theoretical account or a descriptive, factual one. Thus, the way a question is phrased and the kind of answer that is accepted will provide the clues for identifying the view of explanations in science.

For Hanson, language and explanation are laced together and the ability to express oneself so that one is understood by others is a way of communicating knowledge. For school children, such comprehensive communication is not evident. Much of this is due to the way science activities are structured and the amount of discourse permitted or prevented during lessons. Thus abbreviated pupil communication, most obvious in all of the lessons analyzed in this study, compounds the difficulty of identifying the ideas expressed during the activities. Hanson also recognizes the linguistic limitations of children which he attributes to their narrow view of the world. These limitations present pupils with difficulties -- not only in understanding scientific phenomena but also in explaining (their) activities. In the Hansonian sense, theory-dependent language is closely tied to scientific understanding and knowledge, thus

> "Income-tax collector" is a politically loaded expression. "My neighbor" is not. A child can understand "my neighbor"...but to have a rough idea of what "income-tax collector" means, one must have some understanding of the meaning of words like "government," "citizen," "policeman,"... a subtly interlaced background of theoretical and experiential considerations. (Hanson, 1969, p.305).

Children, however, carry on quite well with theory-independent terms such as: sticky, black, hard, soft, which do not assume the extensive body of knowledge and experiences in science usually associated with the activities of scientists.

> The more "phenomenal" a word, the less theoretical it is, the more possible (for little children) to understand it and use it independently of the language system in which it figures. (Hanson, 1969, p.306)

## Theory Related to Practice

It has been argued above that the activites and the language of communication of elementary school pupils are not at the same experiential and intellectual level as those of scientists. Nor is it reasonable to expect elementary school teachers to have the science experiences and knowledge of scientists, yet they do transmit ideas about science to their pupils. Consequently, any attempt to relate Hanson's characteristics of the activities of scientists to the science activities of school children should reflect school reality. Although Hanson's main ideas may be evident, clues which emerge during analysis of lesson discourse may be "mere shadows" of his theoretical conceptions.

Thus it is appropriate, at this time, to suggest how Hanson's theoretical conceptions (as outlined in Chapter III) might translate to the context of elementary school. Since Hanson's separate characterizations are interrelated, characteristics which represent ideas about science in school discourse would also be interrelated, as they are in classroom activities.

## A Sensationalist View

In the elementary classroom the provision of a sensationalist view of science would be more easily recognized and more closely consistent with Hanson's conceptions than would the other views of science. This is because of the age and experience of the pupils and their natural dependence on sensory perceptions, with learning and understanding advancing as they grow and mature. This point is outlined above and is recognized by Hanson. However, it has also been said that children do have a store of experience and knowledge acquired through the influence of their world. Thus they do bring preconceptions to their activities, if only as guesses. In the science classroom, then, manifestations of a sensationalist view would depend upon the importance given to the pupils' own view of their world as opposed to existing scientific understanding.

Thus the pupils' concrete experiences would be considered of greater value in understanding events than science information that is available and conveyed by the teacher (or other sources). The teacher would eschew structure or direction in science activities and would avoid the provision of science information. Pupils' activities would be random and wide-ranging so that as much data as possible can be gathered. This means that young childrens' "natural" visual interests, investigative curiosity, and attempts at making sense out of their experiences would be guided by sensory perceptions and descriptions of "matters of fact". In this way, it is assumed, pupils would gain insight into understanding the material being investigated.

Pupils' observation activities, then, involve gathering as much information as possible through concrete, sensory observations. They talk about their perceptions by describing exactly what they see. (This would be akin to Hanson's reference to a strict, phenomenological, retinal manner of observation.) The teacher's comments would suggest the value of the pupils' descriptions and would encourage random data gathering while avoiding reference to particular observations which should be made or to scientific information about the material observed. Thus under the influence of sensationalist ideas, "scientific" acceptability would rely on concrete observations rather than on preconceived notions of what should be the case.

Simple investigation or complex experimental inquiry would be carried out by the pupils with minimal direction from the teacher as to the procedure or the results to expect. This also means that the teacher would not provide pupils with scientific information about the material being investigated. Rather the pupils would be involved in random (trial and error) collection of data which they report in descriptive terms. This approach to inquiry would be consistent with Hanson's characterization that (on a sensationalist view) scientists carry out their investigations with a "completely open and unbiased mind." Hanson also considers accuracy to be important in scientific inquiry in order to reveal acceptable data. However, this characteristic may be perceived only vaguely in a classroom where the focus would be on few instructions. Reference to precision may be evident in the use of measuring tools during an investigation.

Explanation of events perceived or investigated would be offered by the teacher and the pupils as "sensory descriptions" of concrete experiences, not as theoretical interpretations. Teachers, then, would avoid reference to science information and their questions would expect the pupils to make sense out of their activities by referring to their own familiarity with events and by describing the "real" world as the pupils perceive it. An important clue to a sensationalist view of explanation is the language of communication. As expressed by Hanson, children are quite happy with theory-independent terms which they understand and can readily apply in the context of their activities. Thus, the teacher and pupils would rely on such simple, non-scientific language of explanation. By avoiding introduction of scientific terminology, the teacher also avoids explication of the terms in the larger context of science.

## A Formalist View

A significant characteristic of formalist thought, as expressed by Hanson, is the predominance of theoretical preconceptions. Such prior knowledge and understanding of scientific events takes precedence over sensory familiarity or intuitive understanding an investigator might have. This conceptual understanding is logically reasoned and meaningful to the community of scientists with similar confidence in existing knowledge -- so much so that the purpose of scientific inquiry is, essentially to confirm what the scientific community knows and considers to be scientifically acceptable.

In the elementary classroom it is not the scientific community which directly establishes the theoretical base from which activities are judged to be acceptable or not, it is the teacher. It is the teacher's science knowledge and understanding (acquired in a variety of ways) which establishes the "formal" purpose and direction of the classroom activities. So, if a lesson avoids activities which support the value of pupils' personal experiences in understanding science events, in favour of the provision of science information by the teacher, this would suggest that a formalist view of science is being conveyed. As the source of scientific knowledge, the teacher may decide on the acceptability of pupils' activities, ensuring that the results of these activities "fit into" the teacher's preconceptions -- what the teacher considers to be scientifically acceptable.

Hanson recognizes a formalist view of observation as that which places greater emphasis on assuring that accepted scientific understanding is the basis of what is recognized in observations, rather than the information collected by retinal perceptions. In the classroom, the teacher would ensure that appropriate observations are made by providing certain kinds of material and observation tools or by directing the pupils' attention to certain characteristics of the material being examined. In any case, the pupils' observations would be expected to confirm what the teacher believes is important. Thus the pupils may talk about their observations by repeating what they believe is expected, rather than by reporting what they perceive to be the case. Since the pupils' own perceptions may not coincide with expectations, these would be set aside or altered in favour of that which is acceptable.

The teacher's instructions prior to investigations or experimental inquiry may indicate how a test is to be carried out, what tools to use, and what results to expect. In this way the investigations would be governed by what the teacher considers to be known and scientifically acceptable. The pupils may talk about redoing an experiment or altering the results if these do not confirm what is expected. The teacher's comments would show approval of investigative procedure and results if these correspond with the teacher's own understanding.

In the classroom, explanation of events is very much determined by the way questions are asked and by the kind of answers expected and accepted. A formalist view would be evident if questions are so structured that only certain answers are acceptable. Those answers would include information which the teacher expects and considers to be scientifically acceptable. Just as a scientist would look to existing theoretical structure to be the key to explanation and thus understanding, so too the teacher would provide explanations in the form of statements of fact, or rules or definitions which are logically reasoned from the teacher's own science understanding. In fact, on this view, neither the scientist nor the teacher considers concrete experiences of value in interpreting events because existing knowledge determines how those experiences can be interpreted. Thus, the pupils' explanations are limited to science information they have been given (and recall) and which would agree with the interpretations expected by the teacher. This would be evident by the teacher's acceptance of certain explanations as opposed to others which may be derived from the pupils' or teacher's explanations and what the pupils are involved with -- what they know to be the case.

The above translation may create difficulties in the lesson analysis since it extends Hanson's conception of formalist thought to a limit beyond which such a view would no longer be evident. One confusion which could arise is to distinguish between the philosophical characterization of a formalist view of science, as translated here, and the more commonly and intuitively understood pedagogical characteristics of "formal" teaching. The latter is frequently manifest through teacher controlled, "structured" activities which might mask scientific inadequacy (rather than the philosophical view of scientific understanding). Such evidence might also be interpreted to convey "unacceptable" science information or an "unacceptable" view of science. However, it is not in the bounds of this dissertation to examine the adequacy or inadequacy of information being conveyed in the classroom, or to judge one view of science over another. The focus for the analysis is on characterizing, from a philosophical stance, the messages about science which are being conveyed and how the pupils become aware of those views.

## A Via Media View

Hanson considers this view of science to be a balanced rational approach to scientific inquiry since it assumes an interplay of scientific observation, knowledge of the world, understanding of science phenomena, and definitive experimental inquiry. Only through such a balance, on this view, can scientific theories be built and reported to the scientific community.

Such a view of scientific activity would be the most difficult to identify in school discourse because of the restricted experience and scientific understanding of elementary pupils and because of the abbreviated comments of the children, both of which have been mentioned as characteristic of school reality.

Hanson considers that the purpose of scientific observation, on the via media view, is to recognize significant information and to distinguish it from irrelevant observations. Such distinctions presuppose a "perceptual framework" or set which gives meaning to the visual sensations. In the classroom, the teacher would provide that framework or set by drawing pupils' attention to certain features which they should note as more relevant than others -- because of the purpose of their observation and because of what is known about the material being observed. The significant point is that a reason would be given for the isolation of a particular feature. If observation-enhancing tools are used, the teacher would inform the pupils as to the power and limitations of these instruments and why they are useful in their activity. The pupils would talk about their activity by relating what they perceive to what they know from other experiences, or what they have learned about similar material. In keeping with Hanson's conception, both teacher and pupils would talk about their observations using scientific vocabulary in a way which shows that they understand the meaning of the words and the context in which these are used.

Since elementary school pupils do not have the scientific knowledge and experience requisite for engaging in experimental inquiry in the manner of Hanson's scientists, it is left to the teacher to provide the framework in which the pupils' investigations can proceed. That is not to say the teacher would indicate how an investigation is carried out or what results to look for (as in the formalist view). Rather, the discourse would reveal that the teacher and pupils establish that a problem exists which needs investigation and together they would determine the best experimental procedure. The teacher's role here would be to provide the pupils with the necessary information about the problem and some direction about procedure in order to avoid aimless activity by the pupils, on the one hand, or "over-structured" activity on the other. The pupils' comments would indicate their familiarity with controlled experimental inquiry. The teacher's comments may guide the pupils to recognize some results as more relevant than others because of what is known about the material being investigated. The pupils would compare their results with information that is known about the same or similar material.

Hanson believes that, according to a via media view of science, an explanation is a theoretical interpretation of events or data in a way which establishes a conceptual connection between the event and what is known by the scientific community about the same or similar events. An explanation is a way of conjecturing an appropriate theory. However, elementary school children do not have a theoretical background and explanations, under the influence of a via media view of science, would not be based on the same kind of experience or understanding possessed by Hanson's scientists. In elementary school, the pupils' science experiences include both in-class and out-of-class activities. Their science information is acquired from the teacher as well as from other sources such as books and television.

The teacher's explanations would relate the pupils' classroom experiences with science information given during science lessons, or with information pupils have acquired in other ways. The pupils' explanations would also relate what they "know" about an event, because of their immediate or prior involvement, with what they have been told or have read about such events. These connections would be evident in the way the pupils or the teacher phrase their comments.

Pupils are often asked to "explain" an unusual (or unexpected) observation or experimental result. Such explanations would be "educated guesses" -- a plausible interpretation based on what the children "know" or have learned about similar events.

Under the influence of a via media view of science, Hanson's scientists use theory-dependent vocabulary in their explanations in a way which needs no further explication. During elementary school lessons, "theory-dependent" terms would also be used by both teacher and pupils, but in a more restricted manner. Scientific terms would refer to the immediate topic of the lesson rather than with associated constructs. Furthermore, the pupils' comments would indicate that they understand the meaning of the terms and how these relate to the explanation.

## Summary

Since classroom activities as well as classroom discourse are considered to be the vehicle for the provision of ideas about the nature of science, it was necessary to select science activities which would most probably be evident in elementary school practice. This chapter explored how the three activities of observation, experiment, and explanation were chosen following an examination of science textbooks and school science programmes. (The same three activities were also among those commonplaces characterized by Hanson in his analysis of scientific inquiry according to three views of science.)

The chapter further explored the difference between the experiences and understanding of children and those of Hanson's scientists since this divergence influences the manner in which views of the nature of science might appear in elementary school discourse. Classroom "realities", then, were illustrated by a discussion of childrens' observations and their explanations. This was followed by a general characterization of how Hanson's three views of science might by manifest in elementary school lesson discourse. The characterizations are based on inference from Hanson's conceptions and "logical extension" from his ideas to the context of elementary school practice.

In the next chapter, collection and presentation of the science lessons is explained, since the discourse of these lessons is the data for the study. Following this, Hanson's conception of scientific inquiry and the speculated characterizations become the points of reference for the analysis of three science lessons. The lesson analyses result in the presentation of an initial clue structure for the identification of views of the nature of science.

Notes

1. Three other science textbooks were also examined but not referred to here. They are each different in format and in approach to teaching science and they differ from the books which are reviewed. These were also found to recommend the same science activities with varying degrees of emphasis.

   George, K. D., Deitz, M. A., Abraham, E. C. Science investigations for elementary school teachers. Toronto: D. C. Heath, 1974.

   Kuslan, L. I., & Stone, A. H. Teaching children science: an inquiry approach (2nd ed.). Belmont, Cal.: Wadsworth, 1972.

   Selberg, E. M., Neal, L. A., Vessel, M. F. Discovering science in elementary school. Don Mills, Ont.: Addison-Wesley, 1970.

# CHAPTER V

# CHARACTERIZING CLASSROOM DISCOURSE

## Introduction

This investigator has argued that the development of a scheme for the analysis of elementary school discourse is a practical as well as a theoretical process. Hence the purpose of this chapter (and this study) is not to look for Hansonian ideas in terms of scientists in the activities and discourse of school children. Nor is it to label teachers as holding a particular view of science. Rather, Hanson's characterizations and the translations of how these might be manifest in school discourse are used as points of reference to the identification of the kinds of ideas which might be conveyed in an elementary classroom. Then in order to identify the ideas to which school children are being exposed, three science lessons are analyzed in a reflexive manner -- a back and forth reference to Hanson's characterizations and classroom realities.

The analyses establish that ideas about science, which reflect those of Hanson in the context of elementary school, can be identified in the discourse. Notwithstanding the "blurring" of characteristics, suggested in the previous chapter, many of Hanson's ideas are quite clear in the lesson discourse, whereas others are manifest as vague hints, but they are all at the level of school children and not developed to the extent envisioned by Hanson. The ideas about science are assigned the same Hansonian labels of sensationalism, formalism, and via media and are identified in the discourse through the activities of observation, experiment (investigation), and explanation.

Since identifying ideas about science should take into consideration influences other than the evidence found in lesson interactions, an interview with each teacher is conducted in order to clarify the context of the lesson analysis. The chapter, then, begins with an examination of how the interview is a useful supplement to the lesson analysis. This is followed by a description of the process used for collecting and presenting the data for the study -- the science lesson interactions and the interviews with the teachers. The chapter continues with a discussion of how the clues, which characterize the ideas about science being conveyed, are coded and identified in the lesson analysis. The rest of the chapter is devoted to the analyses of the three science lessons.

Following the analysis of each lesson, the results of the interview with the teacher are examined. The outcomes of the lesson analysis and the interview are summarized as clues which represent the preliminary, "untested" characterizations of ideas about the nature of science which appear to be conveyed, by the teacher, during the science lesson. These preliminary or initial clues will be assessed for their clarity later in the study, not by the same reflexive methodology used for their derivation, but rather by application of the clues to a new science lesson. These initial clues form the basic structure for the categories of the analytical scheme which is presented in Chapter VI.

## Context of Classroom Interactions

Clues, incorporated into an analytical scheme, may permit one to identify the kinds of ideas about science which are communicated during lessons. However, analyzing lessons without considering the context of the classroom interactions would weaken the focus of the study.

The process of conveying ideas and beliefs during classroom interactions includes more than that which becomes evident in the recorded discourse of a lesson. Ideas may have been established in a previous lesson, and the teacher may (or may not) intend to convey certain ideas in a subsequent lesson. Such information regarding the teacher's ideas about science, and intentions to provide for those ideas in a lesson, can be clarified and supported during an interview with the teacher.

The following extract from a science lesson transcription was cited previously and a portion is repeated below. An extract from the transcribed interview with the teacher is also included to illustrate why an interview can be useful in establishing the provision made for ideas about science to be communicated in a lesson.

> Teacher: Right. Positive ions. I'll put that word on here. (T. writes on the board.) So the negative always tries to get to the positive... here we've got a negative (points to a diagram) charge in here. It's just dying to get to the positive, but it can't jump through the air, 'cause the air won't carry electricity. So how can it get from here to the positive part of the battery, Billy?

This extract focuses on the teacher's explanation of the movement of ions and the discourse can be analyzed to reveal that the ideas about science which are communicated to the pupils are consistent with one of Hanson's conceptions of science. However, will knowing something about the context of the lesson provide greater understanding of the teacher's ideas about science, or of the teacher's intentions to make provision for those ideas?

The interview with the teacher, following the lesson from which the above extract was taken, revealed the following dialogue:

> Supervisor: Do you think they (the children) understood the idea that you were trying to convey?
>
> Teacher: Not terrifically well, but I think a few picked up a little bit and I think that's important...It was a very difficult thing to do. But it wasn't my objective to teach them the electron theory.
>
> S: If you look at that dialogue, those electrons were given real status -- "dying" to do things...
>
> T: Well, what were you to do? You can't just say, well that's a little too complicated. That would be ridiculous.

The extract reveals why the teacher chose to talk about unobservable ions as if they were real. His comments suggest that he was not aware that a particular idea of reality was being conveyed. Moreover, his decision to assign anthropomorphic characteristics to the entities appears to be a pedagogical one and a practical way of helping the children understand the movement of ions, without teaching them the electron theory. In this example, the interview serves to reinforce an inference that, for this teacher, use of anthropomorphism is acceptable when explaining "complicated" phenomena.

Thus, an interview may be useful for clarifying impressions conveyed by a recorded and observed lesson, but it is not meant to (indeed it cannot) serve as objective evidence of the context of a lesson.

The teacher may be influenced by the interview process, as much as the investigator may try to relieve interview discomfort. Furthermore, the teacher's views and intentions regarding science lessons are being provided by the same individual who carries out the lesson and who may believe that "something special" must be accounted for. In any case, the interview can serve to supplement the lesson analysis.

With this in mind, this investigator does refer to interviews with the teachers of each lesson analyzed. Such reference follows the analysis of each lesson in order to acquire some idea of the context of the lesson and the provision of the ideas identified.

## Data Collection

A total of seven lessons were recorded for this study. One was discarded because of poor recording and one is held in reserve to be used if needed. All of the lessons were taught by different teachers, at grade levels four, five and six. The choice of these levels was based on this investigator's experience with elementary science teaching. These levels usually are better provided with ongoing science programmes and, because of the age range of the pupils and the diversity of the teaching, the discourse usually has the potential of communicating a wide range of ideas about science.

The teachers were contacted through personal association with the school boards. Thus the choice of classroom and teacher was left to the discretion of the school personnel. When the teachers were introduced to the study, details of the purpose of the analysis were left vague in order to avoid influencing the way in which the teachers might have taught their lessons. However, they were informed that analysis of the lesson discourse would provide clues for the development of an analytical scheme. They were also informed that the purpose of the interviews was to establish the context of the science lesson -- what occurred in a previous lesson and what was planned for a succeeding lesson. The teachers were assured that no judgement was being made about their teaching and that anonymity of teacher and school would be maintained.

All lessons were taped on a Wollensak 3M cassette recorder and in three classrooms a single microphone was placed in the center of the room. This equipment and its location were satisfactory for picking up enough of the pupils' comments for the analysis, although in some classrooms pupil noises made transcribing difficult. In two classrooms the children were grouped for science activities. Consequently, in order to record as much dialogue as possible, the microphone was moved from one group of pupils to another and held there for a sufficient period of time to record pupil interactions. The microphone was returned to a central location for teacher-class discussions. The teacher's voice was usually sufficiently loud and clear to be picked up by the microphone in either location. During the lessons this investigator monitored the recorder, made notes of the classroom activities which could not be otherwise recorded, and noted all chalkboard items pertaining to the lessons. At the same time, the investigator took notes of any points which might need to be clarified during the interviews.

The interviews were recorded using the same equipment and followed as soon as possible after the lesson was given. This was not feasible for one of the lessons and the interview was conducted one week later. This was the only interview during which both the teacher and this investigator had access to the fully transcribed (but not analyzed) science lesson. Immediately before each interview, the teachers were again assured that the purpose of the interview was not evaluative in any way. The interviews served to clarify the objectives of the lessons and the intentions of the teachers during the activities. Other issues regarding the provision of ideas about science were discussed if these had been noted by the investigator at the time of the lessons. On the whole, conducting interviews prior to the lesson analysis did not prove to be the best situation, since the need for particular clarifications surfaced when the lessons were being analyzed -- at a time far removed from the original lesson. Nonetheless, it will be seen that the interviews are used to the maximum advantage.

## Presentation and Coding of Data

The lessons and the accompanying interviews were transcribed and typed in a format suitable for analysis. All of the lessons, transcribed and analyzed, are found in Appendix A. The transcribed interviews, found in Appendix B, are presented in a regular format since they are not analyzed. The transcribed lessons are presented in a two-column format with the lesson dialogue in the left hand column and the analysis appearing beside and to the right of the dialogue. The dialogue is numbered at five line intervals to provide ease in identifying and recording the clues. A new number sequence begins with each new page. The references to pages and line numbers, in the analysis column, are noted as follows:

> p. for page; L. for a single line; LL. for more than one line. An upper case A before the page number represents a page in the Appendix. For example: LL.18-19 or L.1 - p.A30, L.12.

The lessons have been divided into episodes to make the analysis more manageable, but more important, this division serves to mark a shift of topic during the lesson and to highlight the view of science which might prevail in that particular episode. The episodes are noted in the analysis column with roman numerals and with the lines and pages included immediately below and in parenthesis. For example, if episode IV starts at line 5 on page 10 (of the Appendix) and continues until line 25 on page 13, the notation on page 10 is placed in the analysis column beside line 5 and reads:

> Episode IV
>
> (L.5 - p.A13, L.25)

As the clues, which represent the ideas being conveyed about science, are identified in the discourse, these are noted and coded. The coding is derived from the terms Hanson applies to his analysis of scientific activities according to three views of science. The ideas representing sensationalism, formalism, and via media are coded with upper case letters S, F, and M respectively. The science activities are coded with lower case letters as follows:

> a - refers to observation, b - refers to experimentation, and c - refers to explanation.

Then, if the discourse during an observation activity conveys a view of science consistent with formalist ideas, the code would be F-a. The codes S-a, S-b, and S-c refer to those clues which reveal sensationalist ideas about observation, experimentation and explanation respectively. The other clues are coded in the same way. For example, if the discourse of lines 4 to 13 conveys formalist ideas about explanation, then the code preceding the analysis and beside line 4 (or as close as possible to the appropriate line), reads:

LL.4-13: F-c

If an episode is found to convey a single, or a dominant, view of science, this is indicated by placement of the appropriate code beside the episode heading. If the episode also conveys a frequently revealed secondary view of science, the second code is also included, in parentheses. If more than two views of science are evident in the episode, then only the dominant view is identified or no code is assigned to the episode. Thus:

Episode IV: S-c

Episode V: F-a; (S-a)

Episode III

In analyzing the lessons, it is found that some clues are not clearly manifest. Rather, the discourse suggests that certain ideas about science are being hinted at, or are being developed in the lesson. Such clues are considered to be forerunners to particular ideas and are coded with the prefix p. Thus, if the discourse reveals that via media ideas about explanation appear to be developing in the lesson, the code assigned is p-M-c. Use of the prefix makes it easier to recognize that such ideas are evolving. If these developing ideas appear more clearly in subsequent analysis, the prefix is dropped.

The discussion now turns to the analysis of three science lessons.

## Analysis of a Grade Four Science Lesson

This is the first of three science lessons to be analyzed. The purpose of analyzing these lessons is to identify the clues which initially characterize distinctive ideas about science being conveyed in the discourse. As previously stated, the analysis proceeds in a reflexive manner with reference made to Hanson's conceptualizations and to the context of elementary school. Prior to the analysis of each lesson, the reader is directed to a transcription of the lesson discourse found in Appendix A. Perusal of these transcriptions will help the reader to understand the references which are made to the lesson dialogue during the analysis. Each analysis is followed by a discussion of the interview with the teacher and is completed by a summary and a coding of the clues which are exposed in the lesson. The initial clues, which are formulated in this way, are then assessed for their clarity in Chapter VI.

The first lesson is one of a series from the Elementary Science Study unit, Mystery Powders (E.S.S., 1967). The lesson has been divided into four major episodes in order to show the reader how the activities of each episode are repeated during the lesson, except for the fact that a different powder is investigated in each episode.

| | |
|---|---|
| Episode I: | Heat Test and Observations using Flour<br>(p.A1 - p.A7, L.5) |
| Episode II: | Heat Test and Observations using Sugar<br>(p.A7, L.6 - p.A15, L.30) |
| Episode III: | Heat Test and Observations using Salt<br>(p.A15, L.33 - p.A25, L.22) |
| Episode IV: | Heat Test and Observations using Cornstarch<br>(p.A25, L.36 - p.A30, L.24) |

Before examining the analysis, the reader is advised to review the transcribed, analyzed lesson (Appendix A, p.A1 - p.A30) in order to acquire an idea about the topics and the general "flavour" of the lesson.

An overview of the lesson indicates that the ideas about science which dominate the discourse are consistent with Hanson's conception of how sensationalist thought influences science activities. The evidence that this view is being conveyed is provided by the manner in which the pupils make random observations without teacher intervention or interpretation and they describe the results of heating the different powders by using sensory-based vocabulary. The heating activity is certainly not at the level of experimental inquiry to which Hanson refers. However, for the purpose of analyzing this elementary science lesson, the testing is considered to be an example of investigation carried out by school children -- not the kind of experiment carried out by Hanson's scientists. The lesson also reveals the vague attempt at explaining unexpected events by moving beyond a mere description of matters of fact. This attempt is seen as a forerunner to a via media view of scientific explanation.

Because of the repetition of activities and because of dominance and overlap of characteristics which convey the same sensationalist views of science in each episode of the lesson, analysis by episode would result in an unwieldy repetition of the clues. In fact, characteristics representing observation and investigation are so interrelated as to make separate identification difficult. Consequently, the lesson is analyzed as a unit with evidence of the identified clues taken from different episodes. In presenting the analysis, then, the activities of observation, investigation, and explanation are highlighted rather than the individual episodes.

## Investigation

Each group of four to five children has a sterno-type alcohol burner, an aluminum foil dish, a plastic spoon or metal utensil which is used to stir the powders, and a sample of four powders (flour, sugar, salt, and cornstarch) one of which is handed out at the beginning of each heating episode. The pupils are expected to place "some" powder in the dish and to stir the powder as the dish is being heated over the burner. The teacher is responsible for lighting the burner, but the pupils control the amount of heat by moving a damper-like cover over the flame.

While applying heat to the powders, the pupils discuss the observeable changes. The investigation is carried out quite randomly since the pupils receive no instruction from the teacher as to the amount of powder to use, why the stirring is necessary, or the degree of heat to be administered. This is first evident on page A1, lines 13-19. On the same page, lines 3-12, the teacher reminds the pupils that they brought more powder in order to "have enough"; however, the amount needed for testing is left for the pupils to find out, on their own.

> T: This you can judge for yourself
> as you go on -- if you have
> enough, eh? (p.A1, LL.10-12)

Once the burners are lit and the investigation is in progress, no other instructions are given, except for minor references to care in handling the burners (p.A1, LL.20-22 or p.A16, L.1). The pupils are, however, engaged in random investigation of each powder -- for example on page A7, lines 6-21; page A15, line 32 to page A16, line 10; page A25, line 36 to page A28, line 4. The following is an example of the pupils' undirected activity during an investigation:

> P: Stir some more. Stir faster.
>
> P: OK. Keep on turning and stirring. (p.A17, L.3, LL.13-14)

A similar example is found on page A18, lines 29-32. In both situations the pupils appear to realize the need to keep stirring or control the heat. The teacher's lack of direction, then, may be her way of having the pupils become more aware of care, if not precision, as more tests are completed. (And they appear to become so aware.) This would be consistent with a "laissez-faire" approach -- a randomness associated with sensationalism. The interview with the teacher may clarify whether test accuracy is considered to be necessary during the pupils' investigations.

Since there is no real problem to guide the pupils' investigation and they have not been told what kind of results to look for, their comments express uncertainty about what is observed (p.A8, LL.2-16), and any and all results are collected and talked about. This is also noticeable following each test activity when the teacher calls for the pupils' observations. For example:

> T: Let's write down what we have discovered with -- (p.A3, LL.11-12)
>
> T: How many agree that, at the beginning after mixing it, our powder turned out to be lumpy? ...OK. We can go on. What did you also discover after, Sylvain? (p.A6, LL.21-27)

> T: You're gonna miss the purpose of
> our observation. What is the first
> thing that you noticed? (p.A12, LL.9-11)

The implication here is that gathering as much data as possible during a test activity can generate enough information for understanding the results of the investigation, in this case, the effect of heat on the powders. If the success of the test activity is based on having the pupils make random sensory observations, and this criterion is manifest in the dialogue, then the idea being conveyed in the lesson is consistent with Hanson's view of both observation and investigation according to sensationalist thinking.

Although Hanson's ideas about experiment extend beyond the clues noted here, the discourse of this lesson does show some of the characteristics of investigative inquiry which closely approximate those of Hanson. The discourse also demonstrates that the characteristics of observation and investigation are interrelated, as indicated by Hanson. It is this relatedness which makes it difficult to separate one set of clues from the other. Nevertheless, the analysis now includes the identification of characteristics consistent with a sensationalist view of observation.

### Observation

An overview of the lesson reveals that the pupils are preoccupied with making random observations about the powders. Without the benefit of science information and because of their limited knowledge and experience, the pupils perceive everything and accurately use their senses to note the various physical characteristics of the powders.

P: Its gonna come like the----
powder, like before, maybe yellow.

P: Maybe not, because it's----

P: I wonder what's gonna happen. (p.A7, LL.24-28)

Since the pupils are not told what kind of observations to make, or even that some observations are more significant than others, they refer to the powders by colour, texture, smell, and even by taste.

P: It's not black, its brown. (p.A2, L22)

P: It's like vinegar. (p.A8, L.24)

P: The crystals don't go away. (p.A16, L.16)

P: It sticks to the spoon. (p.A21, L.28)

P: It's soft. Touch it. (p.A26, L.28)

P: It tastes awful. (p.A27, L.30)

Moreover, following the testing of each powder, the teacher solicits and accepts the same kind of sense-data information from the pupils, conveying the impression that these are acceptable observations to make during science activities. For example, on page A4, line 13, the pupil comments on the softness of the powder. The teacher follows with a reference to sensory observations, and she insists that the pupil use a description based on his tactile sense.

Sylvain: It comes soft again.

T: By doing what? What are you
doing there?

T: Can you find a better word
for that?

Sylvain: Crunching it.

T: You're not crunching it.
What are you doing to it?

P: Rubbing.

T: Right. (p.A7, LL.13-23)

Further examples of how the teacher encourages the pupils to use their senses in gathering information about the powders can be found on any page of the lesson discourse.

T: I think you all have to put
your little fingers in there.
Feel it. (p.A5, LL.3-5)

T: Right———. What is yours
like, Ann? What do you feel there,
when you --?

Ann: Like sand.

T: Well, what does sand feel
like?

Susie: Soft. (p.A4, LL.23-29)

Significantly, the teacher provides the pupils with no scientific information about the powders and she conveys the impression that the direct sensory observations can provide enough information to reveal something important about the powders. Such "dust-bowl empiricism" is consistent with Hanson's view of sensationalist thought, and characteristics of this view are evident in the discourse. For example:

T: Well what is the colour of
pepper, eh? When you tell me it's
the colour of sand, or salt and
pepper, this is an establishment
that has been done. Somebody
has decided this would be
called pepper, this would be salt.
We cannot say it has the colour
of sand. (p.A5, LL.14-22)

On page A23, the teacher's comment supports this idea that many observations made by the pupils contribute to their knowledge.

> T: You cannot hear what the others are saying when you are talking. So you might have made different observations, but by listening to others we will all put our knowledge together. (p.A23, LL.14-19)

Another suggestion that such sensationalist ideas are being conveyed is evident at the end of each episode. In "finalizing" the pupils' observations, the teacher lists only some of those observations and she gives no indication why she chose to record the dissolving of sugar (p.A12, L.36) or that cornstarch sticks to the teeth (p.A30, LL.18-23). These lists may be the teacher's way of isolating the important observations from the "mass" of data encountered by the pupils implying that among the data encountered, something of importance is revealed which is worth recording. This suggestion is made in light of the teacher's comment at the end of the lesson: "I will leave the notes on the blackboard..." (p.A30, L.34). Furthermore, the listed characteristics refer to concrete evidence of the pupils' perceptions. Both of these clues are consistent with a sensationalist view of observation.

The pupils may have a limited scientific knowledge about the powders, but they have seen, tasted and handled flour, sugar, salt and cornstarch, if only during their previous activities using iodine, water, and vinegar (reference to this is made on page A1, lines 7-9). There is evidence in the lesson of the pupils and teacher comparing results of the heat test on the different powders with the results of the previous tests on the same powders. The following extracts provide such evidence:

> T: ...We have sugar in there. Try to think back children. Remember all our other observations. What happened with the water, the vinegar, the iodine? What happened when we mixed sugar? What happened? (p.A11, LL.14-19)
>
> P: Miss, the salt had crystals but these crystals didn't melt like the sugar.
>
> T: OK. So sugar has crystals and the crystals melted. Salt has crystals and the crystals did not melt. We have to find out——... (p.A23, LL.5-11)

Further examples can be found on page A16, lines 9-11 and lines 18-24; page A24, lines 6-9; and page A29, lines 2-11, 26-41. In all of these the teacher and the pupils carry out sensory observations and gather as much concrete information as possible. The stress is on what is perceived through the pupils' own concrete experiences with the same or similar materials.

The implication here is that varied experiences are useful in gathering as much information as possible about the material being investigated (in this case, the powders). Manifestations of such ideas would be characteristic of a sensationalist view of scientific observation.

Language of communication. Associated with such sensory-based observation is the way in which the pupils and teacher talk about their findings. Throughout the lesson, the words used by the pupils, between themselves, or when reporting their observations, are simple descriptions of what "is in front of their noses". Terms such as brown, crunchy, stinks, black (p.A16), and statements such as "It looks like toffee" (p.A10, L.9), or "It melted and it runs" (p.A14, L.9), or "It remained by itself" (p.A29, L.15), represent the kind of vocabulary referred to by Hanson as theory-independent. The words carry no theoretical preconceptions, no scientific meanings, and refer strictly to affairs of the world within the pupils' own concrete experiences and understandings. The impression conveyed in the discourse, then, is that it is perfectly acceptable to use such phenomenal, descriptive vocabulary when discussing science activities. Moreover, one of the criteria of sensationalist thought about scientific observation is the use of such language in communicating ideas.

Since the lesson appears to focus on undirected investigation during which random, sensory observations are gathered, it would be appropriate to find out from the teacher whether she stressed the same kind of activity in a previous lesson and how such observations contribute to the pupils' scientific knowledge.

## Explanation

The discourse of the lesson revolves around finding out as much as possible about the changes that are observed in the powders as a result of heating. There are, however, a few specific, and brief, efforts by the teacher to help the pupils explain or make sense out of their observations. The following extracts show that the manner in which the questions are asked and the kind of answers that are accepted appear to be consistent with Hanson's rules for recognizing the influence of sensationalist thinking on explaining scientific events.

On page A5, lines 26-36 the teacher uses the word "explain" interchangeably with "discover" as she challenges the pupil to use his tactile sense to describe what has been perceived.

> P: Some of it is soft and some hard.
>
> T: Sylvain is trying to explain that some parts are soft and some other parts are not. But what do you discover when you feel it? Press on it and see what happens.
>
> P: It's lumpy.
>
> T: It's lumpy, yes. Lumpy and rough. And what are you doing with your finger now? (p.A5, LL.26-36)

The teacher's comments convey the impression that in order to explain the differences perceived in the powder, descriptions of sense-data information gathered during random experiences will suffice.

On page A15, lines 11-26, the word "explain" is used in the context of listing the observations. The interchange is initiated by a pupil as he describes the changes he observed in the powder. When the teacher asks him to explain what happened, the question appears to be phrased as if more than a description is desired. However, she immediately stresses the need to record the observation, and she again accepts as the "explanation", sensory descriptions derived from the pupil's own experiences.

> P: When we lifted it in, it was all in -- not one piece. When we shook it, it was just in one piece. But when we pulled it up, it started to get hard but it broke----just like that.
>
> T: So how would you explain that? How are we going to write that on the blackboard? How are we going to write on the blackboard for our observations, for our notes, that sticking of our fork?

P: It stretched.

T: It stretched, yes and then —?

P: Then it turned hard.

P: And it broke.

T: It turned hard, yes (T writes on the board.) (p.A15, LL.11-26)

No science information is provided about the powders to help the pupils recognize patterns in their observations or to suggest how or why the heat affected the powders in the manner observed. Rather "explain" appears to be used by the teacher in a limited, non-theoretical way and could probably be replaced by describe, tell, list or even define without altering the message being conveyed: an "explanation" is a description of reality and sensory information gathered during investigations contributes to explaining and understanding the effect of heat on the powders, without the need for other science information. These two extracts, then, appear to be conveying views about explanation which have characteristics consistent with those expressed by Hanson and those thought to reflect sensationalist ideas in the context of school experience.

On page A9, lines 14-24, a pupil comments on the effect of heat on a plastic spoon used to stir the powder. The teacher's questions appear to request more than a description of what happened: "Well why did that happen?" However, the descriptive responses by the pupils take over the dialogue and the teacher provides no further comment. There is really insufficient dialogue here to identify this as reflecting a sensationalist view of science but there is a hint that such a view may be developing. Another incomplete dialogue is found on page A19, lines 17-31. The children are heating salt, and the teacher tries to elicit a use for salt which they may be familiar with. The questions vaguely refer to home use of salt which the pupils associate with cooking. However, on page A24, line 36 to page A25, line 15 the teacher repeats the question, accepts the pupil's response, and adds that salt is useful for putting out fires.

> T: Why do you think salt would be good then, if it doesn't melt? How would it be useful?
>
> P: Oh, ah, it could put out a fire.
>
> T: Yes, yes! Salt would be very good to put out fires. (p.A24, L.36 - p.A25, L.4)

The teacher, here, provides a functional explanation for the salt which may (or may not) be within the experience of the pupils. Had the teacher continued to relate this usefulness to the characteristics of salt, with which the pupils are familiar, and to information as to how salt "eliminate(s) a fire right away", the explanation would be consistent with a via media view of science. As it is, the explanation refers only to pupils' possible experience, which suggests that it is a development toward a sensationalist view of explanation.

Different ideas about explanation. There are now two extracts to consider which appear to convey a different message from those just analyzed. These are found on page A23, lines 20-29, and on page A24, lines 31-36 and are quoted below:

Antonella: Ours turned yellow,
white and black, sort of,
all sorts of colours.

T: Well, what do you think made
it turn different colours?. You
said it's the crystals that were
turning. Why are some crystals
exactly the same colours?

Antonella: Miss, the fire?

T: Right, on account of the fire.
So the reason, I guess, that
Antonella is giving us, is the
crystals did not turn exactly the
same colour, is due to the intensity
of the fire, eh? The longer you leave
them, the darker they would turn. (p.A23, LL.20-35)

P: Miss, this, like, it came
deeper, every time you heat it.

T: Why? Because it is aluminum
and the more heat you give to it,
it kind of stretches out. (p.A24, LL.31-36)

In both of these instances the teacher attempts to provide the beginnings of an explanation which move beyond a description of sense-data information. On page A23, line 33 the reason for the differences in colour "...is due to the intensity of the fire..." and on page A24, lines 34-36 the reason the aluminum plate stretched is because aluminum acts that way when subjected to intense heat. In the first explanation, the teacher tries to bring together her own knowledge and experience with the powders with the experiences of her pupils. In the second extract, the teacher brings to the very brief explanation her own knowledge about the effect of heat on aluminum and she uses this to support the pupils' observation. In these instances, brief as they are, the teacher appears to be using the kind of explanation that is influenced by via media ideas. In a very limited way she gives a hint (the first throughout the lesson) that the provision of supporting knowledge, other than the pupils' own perceptions, is useful for making sense out of observations.

However, no claim is being made that these two brief divergences, from the otherwise consistent sensationalist ideas being conveyed in the lesson, capture Hanson's criteria for via media thinking. As has been noted earlier in this thesis, the pupils are not at the same conceptual and experiential level of Hanson's scientists. Moreover, from a more practical point of view the teacher is probably unaware of the differences in the way she is handling the classroom explanations. Most important, there is inadequate data in these extracts to substantiate such a claim. Rather, such explanations may very well be forerunners to the kind of explanations that depend on both experiential information and knowledge about the phenomenon (in this case the effect of heat on the powders). Hence the suggestion that these explanations, which include more than sense-data information, are the teacher's way of introducing the pupils to via media thinking about science. This assumption would have to be discussed with the teacher during the interview in order to find out her own views about explaining science events to her pupils and the kind of explanations she had used in previous lessons.

Language of explanation. Explanation of events, at any conceptual level, is expressed through language. Throughout the lesson, the language used by the teacher and the pupils has been notable for its linguistic simplicity--characteristic of sensationalist views about communicating ideas in science. There is no change from this "rule" in the explanatory extracts found on page A5 and page A15.

The language used is simple, descriptive, and entails no body of scientific knowledge. There is one attempt by the teacher, however, to use more complex vocabulary on page A23, line 33: "...it is due to the intensity of the fire..." (emphasis added). "Intensity" is not a phenomenal word (in Hansonian terms) and it implies more than a concrete understanding of heat. The word has to be understood in the context of a background of experience and knowledge about heat. It is unclear why the teacher used this theory-dependent term since her succeeding comments return to experiential, descriptive language. This single use of a complex term was probably unintentional, but its use is characteristic of a via media view of science. Use of the complex term, in this instance, supports the suggestion that the extract in which this word is used is an example of how explanation, consistent with a via media view, could be developing in this discourse. The interview with the teacher might clarify her intentions regarding the use of such scientific terms during classroom activities.

## Contextual Support

The interview with the teacher confirms that sensationalist ideas about science are being conveyed during the classroom interactions. Although the teacher was not aware of the kind of message being transmitted (in philosophical terms), she was very much aware of the purpose of the activity. Furthermore, she appears to have planned this and previous investigations for the children with these very ideas in mind. The reader is advised to review the transcribed interview (Appendix B, p.A141-p.A145) in order to recognize the references made to the teacher's comments.

According to the teacher, the purpose of this and prior investigations was to have the "pupils discover themselves, observe themselves the changes" (p.A141, LL.15-16). No particular results were expected. Although the teacher realizes that the pupils used no precise quantities of powder or liquid, which resulted in various observations, she considers this randomness to be a challenge to them since they would have to decide the quantities needed (p.A142, LL.11-23).

These teacher intentions and considerations are consistent with sensationalist ideas about the way investigations are carried out in science, thus confirming the initial clues identified in the lesson analysis.

Since sensory observations of test results appear to prevail in the discourse of the lesson, the teacher was questioned about the purpose of such concrete observations (p.A143, LL.17-19). The teacher implied that such activities help the pupils retain "something" for the future and to acquire an interest in their science lessons (p.A143, LL.32-39). Unfortunately this point was not pursued. The teacher does realize that the pupils do not have enough science information to understand their observations, yet she considers that providing such information or "names" would satisfy the pupils temporarily, but serve no other purpose (p.A144, LL.8-11). But observation of the changes in the powders, she thinks, would help the pupils understand what occurred during the tests (p.A144, LL.15-17 and LL.23-26).

The comments by the teacher, then, appear to support the claim made that a sensationalist view of observation is being conveyed during the lesson. Moreover, the interview indicates that this view prevailed in the previous lesson and will be pursued in the following lesson (p.A145, LL.28-30).

The interview further reveals that the teacher makes no effort to provide the pupils with a scientific explanation of their observations (p.A143, LL.3-10 and p.A144, LL.3-11). However, she appears to be ambivalent about whether or not to do so. On the one hand, the teacher claims that the pupils' descriptions are inadequate as explanations, but she follows instructions "to be satisfied with what the pupils (find)" (p.A143, LL.3-5). On the other hand, she finds these concrete experiences satisfactory for the pupils' needs (p.A144, LL.4-11). When pressed by the investigator, the teacher felt that "explanations" should be provided until no further questions are asked (p.A144, LL.36-42). However, the kind of explanation was not made clear. The general tone of the teacher's comments implies that concrete experiences which result in physical descriptions are adequate explanation (p.A145, LL.11-21). This supports the clues identified in the discourse as characteristic of a sensationalist view of explanation. Moreover, contrary to the suggestion made in the lesson analysis, that via media views about explanation appear to be developing, the teacher had no intention of providing explanations beyond the simple perceptions obvious to the pupils. Significantly, the teacher acknowledges an outside influence on her behaviour which makes it difficult for her to provide for other than descriptive explanations (p.A144, L.18; p.A145, LL.6-7). Hence it is possible that the teacher's comments reflect, not so much her own views, as those which she has been told to provide in the science lessons.

In any case, except for the clues which represent the development of via media views of explanation, all the clues which are identified as conveying sensationalist ideas about science in this lesson are confirmed by the discussion with the teacher.

These clues, as manifest in the lesson discourse, are now summarized and coded.

## Identification of Initial Clues

Sensationalist ideas about investigation. No claim is being made that the pupils' heating activities capture Hanson's conception of what scientists do and consider during experimental inquiry. The suggestion being made, however, is that sensationalist thought is influencing the ideas transmitted during the heat tests; such thought is evident in the random manner in which the investigations are carried out and the results collected, without the benefit of background knowledge or preconceptions about the test procedure or the kind of results to expect. Also, as much information as possible about the powders is gathered and recorded. The discourse also implies that the sense-data information collected can generate important information for understanding the material being investigated. Even though these characteristics are a "blurring" of Hanson's conceptions (hence the term investigation instead of experiment), they are consistent with those clues it has been suggested might be evident in school discourse, if sensationalist ideas about investigation are being conveyed.

It is interesting to note that the teacher's guide for the unit on Mystery Powders (E.S.S., 1967) states that the test activities are meant to be introductions to "investigatory science".

> While Mystery Powders is not a unit in formal Chemistry,...it has been found particularly useful for introducing both teachers and students to investigatory science. (Elementary Science Study, 1967, p.1)

Hence there is support for considering the heat tests (and the previous tests carried out by these pupils) as an example of experimental inquiry at the elementary school level. This is confirmed by the interview with the teacher.

For these reasons, the initial clue structure, shown in Figure 2 identifies those characteristics which represent sensationalist ideas about investigation as identified in this lesson. These are coded S-b in the lesson analysis found in Appendix A (p.A1 - p.A30).

Sensationalist Ideas About Investigation: S-b

The following clues reveal that sensationalist ideas about investigation are being conveyed during this science lesson:

| Characteristics | Examples from Discourse |
|---|---|
| Ps carry out tests in a random manner without T direction about procedure or the results to expect. | "This you can judge for yourself as you go on..." |
| T and Ps gather as much sense-data information as possible from various tests. T seems to assume that results may generate important information. | "Let's write down what we have discovered..." |

Figure 2. Characteristics of initial clues to sensationalist ideas about investigation.

Sensationalist ideas about observation. According to Hanson, scientists influenced by sensationalist thought carry out scientific observations by randomly using all their senses. The assumption is that no preconceptions impinge on the gathering of as much concrete data as possible. Thus valuable information will be revealed. Since young children have limited experiences, they do use their senses extensively to examine their environment. Moreover, the discourse of this lesson provides evidence that the pupils are so engaged. The teacher provides no information for the pupils to apply to their observations and, throughout the discourse (with only one or two exceptions), both the teacher and pupils use simple, descriptive, non-scientific language to talk about the sense-data information collected through the pupils' personal experiences with the powders. Thus a sensationalist view of observation is being conveyed in the lesson.

Characteristics of the clues which initially represent such ideas are listed in Figure 3. The clues are coded S-a in the lesson analysis found in Appendix A (p.A1 - p.A30).

## Sensationalist Ideas About Observation: S-a

The following clues reveal that sensationalist ideas about observation are being conveyed during this science lesson:

| Characteristics | Examples from Discourse |
|---|---|
| Ps are preoccupied with random sensory observations. They perceive what is concrete and obvious, through the use of their senses. | "It's not black, it's brown."<br>"It smells like popcorn." |
| T solicits, accepts as much sense-data information as possible from Ps which is derived from Ps' own experiences. | "It's lumpy, yes. And what are you doing with your finger, now?" |
| T and Ps talk about observations using descriptive, non-theoretical language. | "It's bubbly."<br>"They're crystals." |
| T does not provide scientific information about the material being observed. Ps not told what to look for. T seems to assume that observations may reveal something of importance. | "...what did you observe?"<br>"What did you discover after?"<br>"Ah, that's something you noticed." |

Figure 3. Characteristics of initial clues to sensationalist ideas about observation.

Sensationalist ideas about explanation. The lesson analysis appears to suggest that the teacher is conveying two different views about scientific explanation. The one, which is consistent with sensationalist thought, stresses that an account of the changes that occur to the powders can be derived from descriptive, sensory perceptions, without the benefit of other information about the powders. The explanations are communicated in the discourse through the use of phenomenal language.

Via Media ideas about explanation. The second view is brief and it is presented here only as a forerunner to via media ideas about explaining scientific events. By referring to both the pupils' experiences and her own knowledge about the material, the teacher appears to provide a hint of one of the criteria of Hanson's "balanced" view about accounting for unusual events observed. (This interpretation presents the teacher as the representative of scientific knowledge, of course.) Even though the interview with the teacher indicated that her intentions were otherwise, the interview also revealed the teacher's uncertainty about the kind of explanations to provide. The clue, then, as manifest in this discourse, could be an idea of what the teacher would like to develop, but has difficulty doing so; at very least the clue suggests the characteristics which might be manifest if via media ideas about explanation were being developed in the lesson.

In either case, it must be recognized that the explanations identified in this discourse do not entail the scientific experience and knowledge associated with scientists. However, explanations are being solicited and accepted and these are attempts to forge an understanding of what is happening during the investigations. The claim made is that a sensationalist view of explanation prevails in this lesson. This view is considered to be consistent with Hanson's conception since such a thought structure assumes a restricted view of the world and a lack (or disregard) of science preconceptions. This is evident in the discourse and happens to "fit" the developmental and experiential level of the pupils.

Then, the initial clue structure found in Figure 4 identifies those characteristics which indicate that a sensationalist view of explanation is being conveyed. This view of science is coded S-c in the lesson analysis found in Appendix A (p.A1 - p.A30).

Figure 5 presents the characteristics of forerunners to via media ideas about explanation. Since these ideas appear to be developing in this lesson, they are coded p-M-c in the lesson analysis in Appendix A (p.A1 - p.A30) to indicate that such a view of science is evolving.

### Sensationalist Ideas About Explanation: S-c

The following clues reveal that sensationalist ideas about explanation are being conveyed during this science lesson:

| Characteristics | Examples from Discourse |
|---|---|
| T's questions may use "why", "what..." or "how do you know", or "explain", in the same context as describe, tell or discover. Refers to Ps' own experience. | "How would you explain that?"<br>"Do you know why it sticks?" |
| Ps answer or explain with sense-data descriptions of what is concrete, and has been experienced. | "It stretched...and it broke." |
| T and Ps use simple, descriptive non-theoretical language to explain events. | "It turned hard."<br>"It melted and it runs." |
| T does not provide science information in explaining events experienced. | "What do you discover when you feel it?" |

Figure 4. Characteristics of initial clues to sensationalist ideas about explanation.

## Via Media Ideas About Explanation: p-M-c

The following forerunners suggest that via media ideas about explanation are being developed during this science lesson:

| Characteristics | Hints from Discourse |
|---|---|
| T's explanation uses BOTH what is known about the material (science information or experience) and information from Ps' own experiences with the material. | "Because it is aluminum and the more heat you give..." |
| T and Ps use complex, scientific vocabulary when explaining events. | "...intensity..." |

Figure 5. Characteristics of forerunners to via media ideas about explanation.

## Analysis of a Grade Five Science Lesson

The topic for this lesson is not derived from a particular science programme, rather it is a choice of the teacher because of his own interest and background. The division into episodes highlights the thrust and development of the topic, since the reader is not otherwise apprised of the purpose of the lesson until page A51 of the transcript--well into the lesson dialogue. The reader is advised to peruse the complete lesson transcription, entitled Seed Formation and Dispersal, found in Appendix A (p.A31 - p.A68) prior to examination of the lesson analysis. Without such a preview, the analysis and identification of the clues will not be meaningful.

| | |
|---|---|
| Episode I: | Review of Plant Structures<br>(p.A31, L.1 - p.A35, L.28) |
| Episode II: | Seed Formation<br>(p.A35, L.28 - p.A42, L.2) |

Episode III: Specific Case of Seed Dispersal
(p.A42, L.3 - p.A53, L.5)

Episode IV: Seed Dispersal
(p.A53, L.5 - p.A68, L.3)

The pupils are seated at their desks during the entire lesson while the teacher conducts a question and answer format from "the front" of the classroom. The pupils have no material to which to refer until episode IV, at which time they are given a page of labelled illustrations of seeds and see-bearing plants (appended at the end of the lesson transcription (p.A69).

A review of the lesson reveals that formalism is the most predominant view of science being conveyed in the discourse. This view is most prominently provided by the manner in which the teacher structures the explanation of events, and less so by the way limited observations are used to derive information about plants and seeds, with both activities influenced by the teacher's own science understanding and interpretation. In three episodes, however, there is evidence that a sensationalist approach to explanation interrupts the prevailing formalist view. Significantly, the sensationalist manifestations confirm clues identified in the first lesson analyzed, thus lending support to those initial clues.

Moreover, in episode III there is a brief indication that ideas associated with a via media conception of science are being developed through explanations provided by two pupils.

Analysis of the lesson by episode, rather than as a unit, enables this investigator to show how provision of the formalist view swings from observation to explanation within an episode. Such a procedure also exposes how the snatches of sensationalist ideas and a single hint at a via media view intervene in the otherwise formalist discourse. Unfortunately, such episodic analysis results in a duplication of the formalist clues being identified. In order to minimize such repetition, an effort is made to highlight certain clues in each episode without isolating them from the same clues found elsewhere in the lesson.

It is to this evidence that the analysis now turns. The interview with the teacher is examined in order to clarify contextual issues which arise. The identified clues are then summarized and coded.

## Episode I

The first page of this episode provides the initial evidence of a formalist view of science which is encountered in this lesson. On page A31, the teacher recognizes the pupils' prior experiences and their own observations of developing bean plants, but he solicits from them particular information of what they observed and in the correct order in which the developments were seen (p.A31, LL.4-21).

> T: The first thing we saw was a root, that's correct. What came next, after a few more days? We watched them and then we put them in the soil. What was the next thing that appeared? Chris?
>
> P: Stem.
>
> T: The stem was the next thing. That is correct. And what was the third thing that appeared...? (p.A31, LL.8-18)

The brevity and uncertainty of the pupils' comments are suggestive of their search for observations that agree with the teacher's expectations.

> Peter: The beans,----the
> little things -- comes out.
>
> T: Yeah, and what are those
> little things?
>
> P: The seed coat?
>
> T: No, not the seed coat.
> Chris?
>
> Chris: Buds.
>
> T: No, they aren't buds.
> Peter said one of the words.
> He actually said the word but
> be didn't say it----... (p.A31, LL.22-33)

The teacher's comments imply that what was observed during prior activities is important only in so far as those observations include or refer to science information that is known and understood by the teacher but not necessarily what the pupils recognize as important, since their own knowledge and understanding are limited. This characteristic is consistent with a formalist view of observation.

At this point in the episode the teacher presents what appears to be an "open invitation" for a description: "What happened next, Sharon?" (p.A32, LL.11-12). Such a question does not necessarily require sense-data information as a response, but the teacher does accept the pupils' descriptions of what was seen -- observations derived from their personal experiences (p.A32, LL.13, 23, 30, 35, 41). In particular the teacher notes these observations as valuable, especially for those "who were lucky enough" to see the beans developing (p.A32, LL.24-28). This brief interaction could be considered to convey a sensationalist view of observation. However, the teacher's subsequent questions are not open-ended. Rather, these are carefully structured and sequenced to ensure that the pupils recall particular information which the teacher can accept because it fits his scientific understanding about what the observations should include. Furthermore, the teacher's reference to how lucky some pupils were to have seen the bean (p.A32, LL.24-28) could imply that he hoped the pupils would make this observation and was pleased to note that some had, thus fulfilling the (formalist) goal of assuring certain observations are made during science activities. These characteristics suggest that the formalist view of observation, begun on page A31, continues to be conveyed to the end of this extract on page A32.

The interview with the teacher may clarify how much importance he assigns to the pupils' own observations.

The rest of this episode (p.A33, L.1 - p.A35, L.26) reveals that the idea being conveyed is still formalism, with the associated characteristics, but it is provided through pupil-teacher interaction which swings from observation to explanation. Although this view is considered in more detail in the analysis of episode II, certain characteristics are identified here in order to show the variety of manifestations that are possible in a lesson and to support the claim that a formalist view of explanation dominates the lesson discourse.

On page A33, lines 5-11, the teacher refers to a labelled diagram -- a copy or model of the parts of a flower. As such it can be used as an observation-enhancing device to extend the visual perception of the observer to the interior of the flower, not normally visible. If, however, the diagram is meant to serve as a clue to help pupils focus on the appropriate terms for the parts of the flower (as it does in this case, p.A33, LL.5-6) then its use would be consistent with a formalist view or a diagrammatic source of special information or rules for pupils to use when talking about their experiences. The teacher's question may employ experiential descriptive language -- "What do we call those leaves that turned yellow?" (p.A33, LL.1-3, 9-11) -- but he accepts the term which he considers to be appropriate, even though it is not scientifically correct to refer to "petals" as "leaves" (LL.12-13). Nevertheless, he accepts this answer implying that it is appropriate and he expected this label to be given. These characteristics imply that a formalist view of explanation is being conveyed.

The rest of page A33 continues to reveal the influence of the teacher's expectations. These are seen to be more important than the pupils' own comments which are drawn from their own prior experiences. After asking for a review of the three most important parts of a plant, the teacher accepts two and rejects the third: "No. Two out of three is not bad though" (p.A33, LL.26-27). Later, the teacher's question is answered by Michael: "Well, because the flowers are only used once a year for pollination, but the plant stalk grows all year" (p.A34, LL.2-5). This is a plausible reason and is accepted by the teacher. Significantly, Michael's explanation is (most probably) a result of science information acquired during this or a prior lesson and is not an interpretation based on his own understanding and experience with plants (especially since school children usually consider the flower to be an important part of a plant because of its seed-bearing role.) The discourse on page A34 reveals a carefully reasoned set of questions and statements by the teacher so that the explanation that evolves includes science information he considers to be important -- of greater importance in accounting for the role of flowers -- than is suggested by the pupils. Such teacher reasoning continues on page A35 and implies that a successful explanation should be derived from acceptable science information irrespective of what is understood through experiences -- a formalist impression about scientific explanation the characteristics of which overlap with those found in the analysis of ideas about observation in science.

Episode II

The word "explain" is used by the teacher only once (p.A36, L.18) however there are ample indications that an explanation is expected by the way the teacher considers the science knowledge he conveys to his pupils, through a reasoned set of rules, to be of greater significance in accounting for events than their own interpretations. He conveys this message by limiting the pupils' explanations to a repetition or a confirmation of information learned. The formalist view of explanation conveyed in episode I continues in this episode. An example is found on page A35 and continues to page A36.

> T: What is pollination?
> Elan?

> Elan: When the anthers break
> and release what's inside them
> and then it goes on a stigma
> and then after you're gonna
> have some bean pods, I think.
>
> T: Oh. That covers it pretty
> well. (p.A35, L.43 - p.A36, L.8)

The apparent uncertainty of Elan's answer is evident by "I think" and suggests that his comment (as Michael's did in episode I) refers to the "rules" (for pollination) he has learned rather than derived from his own experience with plant pollination. The teacher's acceptance implies that the pupil's answer is adequate, yet he proceeds to solicit more details. From page A36 until page A39, the teacher focuses his questions and extends the pupils' interpretations, by using logically sequenced statements, in order to derive suitable explanations of cross-pollination (p.A36), fertilization (p.A38), and reproduction (p.A39). In this way he appears to build a formal structure from what he knows to be scientifically acceptable and which he expects the pupils to refer to in their interpretations. The following extract demonstrates that the pupils have no personal experiences from which to draw (they are not likely to have seen seeds developing, p.A39, L.24) so their own reasoning is bound to be limited to what they "know" or remember and to confirming what is expected by the teacher.

> T: ...what happens
> inside the flower when reproduction
> takes place...What else
> happens? Sharon?
>
> Sharon: The seeds get bigger and
> bigger.

T: The seeds begin to develop inside.
If they are very small when
fertilization takes place, they
begin to enlarge and develop. What
else happens? James?

James: The anthers die in the plant.
The petals close up.

T: Right. (p.A39, LL.16-31)

Hanson points out that a formalist view of explanation involves applying theoretical preconceptions to predicting future states of affairs, thus "predicting x is explaining it before it has actually happened" (Hanson, 1971, p.43). In certain parts of this episode, the teacher associates prediction with explanation by the structure of the questions he asks. For example:

T: Now, what happens inside
the flower, then? Let's
say we've got a flower on our
plant, what must happen to the
flower, James? (p.A35, LL.28-32)

T: What has to happen
to the pollen once it gets onto
the stigma? (p.A36, L.41 - p.A37, L.2)

These questions limit the pupils' explanations to science information which is known and confirmed by the teacher, since the pupils cannot be expected to draw from their own experiences. The same type of question appears again in episode III.

During the interview with the teacher it would be useful to find out how the pupils acquired science information and how they are expected to account for events with which they have no personal experience.

Particularly noticeable in this episode is the teacher's expectation that pupils use acceptable scientific terms as part of their explanations and in many instances as *the* explanation.

T: It's pollen. And what word
comes from that? (p.A36, LL.13-14)

T: What do we call that
wide part of the flower? Ina? (p.A37, LL.31-32)

T: Now what do
we call that process? (p.A38, LL.9-10)

T: That's a good word to know. (p.A38, L.23)

The words pollination (p.A36), ovary and ovule (p.A37), fertilization (p.A38), and reproduction (p.A39) are all complex, theoretical terms used in science. In Hanson's view, such a vocabulary assumes a body of knowledge about plant reproduction. Moreover, use of such theory-dependent terms also assumes an understanding of the context in which they are referred to. This would be consistent with a via media view of science rather than a formalist view. Indeed such understanding is *not* evident in this discourse. As in episode I, the pupils use these scientific terms in single-word or very brief responses to the teacher's questions. Examples of such brevity are seen on page A36, lines 12, 15, 34; page A37, lines 33, 36; page A38, lines 5, 28; and on page A39, lines 3, 40. In none of these examples is further clarification derived from the pupils other than simple descriptions (p.A37, LL.17-18 or p.A39, LL.22, 29, 36).

The teacher further expands the explanation by providing what appears to be formal definitions of the special terms. For example on page A38, lines 6-29, the teacher "defines" the process of fertilization by a careful reasoning that fits the theory *he* knows (LL.6-15), and he is surprised that "only one person remembers" what the process is called (L.26). The teacher continues to insist on the particular term of reproduction even when a pupil offers his own reasonable account of what happens following pollination and fertilization.

> T: What do you call them when you
> put them together? Clement?
>
> Clement: You get a seed.
>
> T: You get a seed. Correct
> but what do we call that process
> that gives seeds? (p.A38, LL.38-43)

This is an example of how the teacher, focusing on his own theoretical background, can limit the way in which a pupil accounts for events. The teacher gives a qualified approval to Clement's statement, and favours a more acceptable scientific term the meaning of which has been developed through a logical series of steps (p.A37 - p.A38).

Application of such scientific terminology is not specifically recognized by Hanson as a characteristic of formalist thought, but such terms are established by the scientific community and thus can be considered integral to "existing theoretical knowledge". For the purpose of this analysis, these terms are seen as formal rules within a theoretical structure. Then, expecting pupils to use such rules in and as explanations does limit their interpretations to a confirmation of what is known and scientifically acceptable, without the support of their own experience or understanding. This is considered to be a (another) way of characterizing formalist ideas about explanation conveyed in the discourse.

In any case it would be useful to find out from the teacher, his view of the provision and significance of such formal rules (terms) in explaining and understanding science.

Near the end of this episode there is a brief indication that the teacher has a problem in providing the usual formal explanation about the growth of onions because he is really uncertain of his own information. The confusion is initiated by two pupils, Michael (p.A40, L.3) and Clement (p.A40, L.21).

> Michael: An onion grows in the ground. (p.A40, LL.3-4)
>
> Clement: Onions don't grow seeds.
>
> T: That's right. Onions are more a root type thing underneath the ground. Onions will sprout, but they don't have seeds inside them.
>
> Clement: Then how do they grow?
>
> T: Well, the onion plant has seeds, I was wrong, but the onion is more of a root or bulb that grows and makes the plant. But it's not the seed, as far as I know. (p.A40, LL.21-34)

Even though the teacher's uncertainty shows in line 33, "But it's not the seed, as far as I know", he does not encourage either Michael or Clement to expand their comments which appear to be drawn from their own experience. Rather he compounds Clement's misunderstanding by adding a confused set of statements. It is not in the bounds of this study to judge the adequacy of the teacher's scientific understanding, but the exchange still conveys a formalist view of explanation because of the way the teacher provides what *he* considers to be an appropriate explanation.

Notwithstanding the preceding analysis, the teacher does consider pupil experience to be of some value in understanding and interpreting science. He refers them to their familiarity with seeds found in fruit and he suggests that they examine a banana for the presence of seeds so that they would understand that fruit contains seed (p.A41, LL.2-44). In this digression, the pupils' and teacher's explanations involve a description of the world (of fruit) as the pupils know it. Had the teacher related these pupil understandings to the previous science explanations about the enlarged ovary and fruit (p.A39, LL.24-41), this discourse could convey a via media view of explanation. However, the teacher does not make this connection. He does provide his usual extension but this time he refers to the pupils' experiences and their comments are considered to be important. This brief extract, then, conveys a sensationalist view of explanation in an otherwise formalist discourse.

## Episode III

The discourse of this episode continues to convey the formalist view of explanation begun at the end of episode I with only two brief and unexpected exceptions. At the beginning of the episode, the teacher uses a diagram of coconut trees as a specific case of seed dispersal (p.A42, LL.3-10). Significantly, except for Clement and possibly Chris (p.A42, L.15 and p.A43, LL.18-36), neither the teacher nor the pupils have a personal familiarity with coconuts (p.A42, LL.7-20). The diagram, however, becomes the focus of the pupil-teacher interaction which reveals the teacher's continued reliance on prediction-type questions.

> T: ...What's going to
> happen to those seeds now?
>
> Ps: Oh! Oh!

P: They get bigger.

T: They might grow a bit
bigger. Once they get to full
size, once they are mature and
ready to fall off, what should
happen? (p.A42, L.32 - p.A43, L.3)

The two questions in this short extract reveal the kind of request referred to. The pupils do not appear to know what information the teacher wants since they lack the understanding and familiarity with coconut trees. This is revealed by their answers "Pollination" (p.A43, L.4), and "I mean, ah" (L.6). Then again, the response "They get bigger" is a logical answer to the teacher's question, especially since this development of seeds had been discussed moments before (p.A39, LL.22-29). Andrew's answer on page A44, line 23, is also a reasoned response to the teacher's request for a prediction (p.A44, LL.19-23). Nevertheless, after accepting Andrew's comment the teacher follows with some associated information and a more specific question, one which asks pupils to make a judgement: "Do you think there could be any problem on that particular island? When you think that there could be 20-100 coconuts falling off a tree" (p.A44, LL.28-32). Such a question is an example of the kind of deductive framework in which the teacher's questions are organized, and is characteristic of a formalist view of explanation.

Two extracts in this episode continue to convey the idea (found in the last episode) that appropriate scientific terminology should be used in an explanation, irrespective of the pupils' understanding of the term. From page A46 until the term photosynthesis is used on page A47, line 20, the teacher uses structured questions which eventually derive the scientifically acceptable "word I'm looking for" (p.A47, L.4) while the pupils' answers reveal that they are uncertain about the teacher's expectations.

The second example of the need to use correct terminology when speaking about plants is found on page A50, "Now the word I want to give you today is this word [dispersal] and someone ... can tell me what they think it is" (LL.29-33). In the brief dialogue, which continues to page A51, line 20, the teacher does try to relate an interpretation of the term dispersal to the preceding discussion: "Does anyone have any idea what dispersal is all about? Using what we have been talking about so far..." (p.A50, LL.35-38). After accepting Clement's brief answer "Spreading" (p.A51, L.3), the teacher continues to provide a scientifically based explanation or definition of dispersal. Had the teacher solicited more information from Clement's experience and related this to the information about seeds conveyed during the lesson, the extract might have conveyed a via media view of explanation. Rather, the teacher not only provides a definition of the term but this becomes the rule in accounting for seed dispersal in the final episode.

A brief interruption of the formalist message is found in an attempt by a pupil to apply his own experience with and understanding of coconuts to an explanation. Clement recognizes the coconut tree in the teacher's diagram (p.A42, L.15), and he later uses his knowledge to answer the teacher's persistent question.

T: ...These round
things you see hanging are the
seeds. The seeds are inside
the coconut. What should
happen? Clement?

Clement: Well, after, the
coconuts will fall off the
tree and hit the water.

T: They might. The coconut
is definitely going to fall off. (p.A43, LL.13-22)

Clement is also aware of the large number of coconuts that a tree bears, "...sometimes there are three big branches and coconuts like mad!" (p.A43, LL.25-27) and he understands how the coconut is dispersed, "Big waves" (p.A49, L.5). (In fact Clement's experiences are derived from his native home in the West Indies, a point which is not obvious to the reader, but which is known to the teacher.) However, the teacher does not help Clement expand his answer. Rather, the teacher continues to focus on specific information and questions in order to ensure that the explanations that are derived fit his preconceptions about the relationship between the numbers (of coconuts) and seed dispersal (p.A43, LL.23-24 and L.6 - p.A44, L.7 and LL.30-32).

In this interruption it appears that only the pupil, Clement, is trying to make sense out of the problem by referring to his own understanding. This suggests that the pupil has a view of explanation based on what he knows from concrete experience. Such a sensationalist conception is not conveyed by the teacher's dialogue; however, it is being analyzed as a sensationalist view of explanation -- by a pupil.

It is interesting to note that following this brief interaction, as the teacher continues to focus on predictions of what might happen to the coconuts, two pupils, Fanny and Michael, introduce another view of science through their explanations. On page A44, lines 32 and 36, the teacher's speculative questions release an answer from Fanny in which she appears to see a connection between the teacher's previous comment (LL.24-32) and what she knows (or remembers) from prior information about crowding of seeds. Up to this point in the lesson, this particular information has not been provided by the teacher.

> T: ...What do you suppose can happen? Fanny?
>
> Fanny: There's gonna be too many trees on the island.
>
> T: And what's gonna happen as a result of that?
>
> Fanny: And when the other trees grow coconuts there's going to be more trees and there won't be enough room for all the coconuts. (p.A44, LL.32-41)

The teacher follows Fanny's interpretation with a question that requires a further clarification--the kind of request not previously made by the teacher (p.A45, LL.2-3). Michael, in response, also uses the teacher's clues as well as information about crowding and survival derived from the lesson discourse to provide a scientifically satisfactory explanation of what might happen to coconuts. Both Fanny and Michael, then, attempt to set the new problem (about coconuts) into a conceptual pattern with other similar, related events to present a logical explanation (temporarily) acceptable to the teacher. The dialogue is presented below.

> T: You say there won't be enough room. What does that mean, there won't be enough room? Michael?
>
> Michael: Because if you have too many on one island, say the trees here are full of coconuts, and a coconut falls right here and starts to roll and before that all of the other coconuts have a head start and they grow and he's just starting to grow, what happens is they would block out the sunlight and he can't grow.
>
> T: Very good answer. (p.A45, LL.1-16)

According to Hanson a via media view of explanation requires a background of understanding and knowledge as well as experience with related events in order to account for a new problem in a meaningful way. In this discourse, in fact in this lesson, such a background of understanding is not evident. The pupils' answers and comments attest to that. A limited investigation of a few coconuts as well as experiments on seed crowding might have provided a further bridge toward a via media view of science. Consequently, the brief discourse is considered to reveal the beginnings of such a view of explanation, and most significantly, it is evident in the pupils' conceptualization.

Following this interruption, the discourse continues to convey a formalist view of science as the teacher's questions build the same logical explanation given by Michael. The implication of this continued development of a set of rules for explaining the effects of seed crowding and dispersal may be the teacher's way of ensuring that all pupils acquire the necessary information for understanding these scientific phenomena.

The interview with the teacher may be an opportunity to determine what kind of personal experience and information he sees as important in helping pupils understand the events being discussed.

### Episode IV

The analysis of this episode is presented differently from the previous analyses. Two issues led to this decision. First, no new clues are revealed in the discourse. The same characteristics of a formalist view of observation and explanation are evident as in the previous episodes. Straight analysis, then, would present an unnecessary repetition of clues. Second, and more significantly, this episode reveals how ideas about science can alternate within an episode, indeed within the time-space of a few words of discourse. There is evidence of a shift from a formalist to a sensationalist view of science, and although the formalist view predominates in the episode, these formalist ideas appear to be provided alternatively between observation and explanation. Moreover, these latter clues are not often clear. This lack of clarity may be a factor of the material used by the teacher, or of the acknowledged relatedness of the two activities.

The present discussion, then, presents brief examples of the formalist characteristics found in this episode, as well as the clues in identifying the sensationalist view. The analysis then reveals where the shifts of idea occur in the dialogue between a sensationalist and a formalist view and between the activities of observation and explanation. The reader is advised to peruse the full analysis of this episode again (Appendix A, starting on p.A53), in order to identify these interchanges.

The teacher introduces the episode with a work-sheet containing labelled diagrams of various seeds and two seed-bearing plants (Appendix A, p.A69). This is the second indication that the teacher considers that some form of pupil observation may be helpful in generating an understanding about plants, and in this case, about seed dispersal. In episode I, a formalist view of observation was conveyed by the manner in which reference was made to the observations pupils had made during a prior activity. In this episode, the work-sheet is the teacher's way of limiting the pupils' observations (vicarious as they are) so that acceptable observations are made. Since the pupils have only a limited experience with a few of the represented seeds (p.A53, L.44 - p.A54, L.11) they must rely on the illustrations presented. These replace the need for pupils to handle real seeds. In the following extract the teacher indicates that distinguishing features can be found among the illustrations and these provide the clues pupils need in order to understand seed dispersal.

> T: Look at the various seeds on
> here and see if you can figure
> out how the plant uses nature
> to spread these seeds around. (p.A53, LL.8-11)
>
> T: There's a little clue
> there that gives it away. (p.A54, LL.2-3)

A formalist view of explanation is revealed by the teacher's questions which request the pupils to account for situations with which they are unfamiliar. This view is evident throughout the discourse between teacher and pupils regarding the seed dispersal of the lotus plant (p.A54, L.12 - p.A58, L.36).

> T: Why are the holes
> smaller than the seeds? (p.A54, LL.43-44)

Furthermore, the teacher uses formal reasoning derived from his own scientific knowledge to provide the acceptable explanation which the pupils would not otherwise derive because of their limited experience and understanding. An example of such an extended account is found on page A58, lines 9-36.

Page A61 reveals an example of the difficulty encountered in isolating the characteristics which distinguish between observation and explanation. The teacher's question on lines 14-15 is a request for an explanation: "Why would a dandelion make its seeds like that? What's the point?" The expected reason, in this example, can be and is, derived from the discussion between the teacher and pupils (p.A59) as well as from recognition of the clues in the illustration (p.A60, LL.34-42). Thus the interdependence of observation and explanation hinders clear identification. Nonetheless, it is the view of this investigator that some effort must be made to distinguish between the activities, even though the main characteristics of a formalist view of science are found in both activities. In this case, the context of the discourse suggests that the view of science is provided through explanation since the teacher's careful comment prior to the question assured the appropriate answer given by the pupil (p.A61, LL.8-18). It is interesting to note that following this explanation, the focus changes to observation with a return to the illustrations (p.A62, LL.1-19).

The sensationalist view of explanation is identified when the teacher and Paula talk about dandelion seeds (p.A59, LL.5-13) and later, when Andrew and Michael describe their experiences with the milkweed plant (p.A62, L.25 - p.A63, L.30). In these examples the teacher's questions are a request for information or an explanation that is derived from the pupils' own familiarity with the plants.

The first contradiction of ideas begins on page A58, line 37, where the teacher refers the pupils to clues to be found in the worksheet illustrations. He thus ensures that the pupils will make certain observations about seed dispersal. This conveys a formalist view of observation. Paula notes the dandelion and the teacher's subsequent question is a request for information based, not on what the pupil sees in the illustration but on what her familiarity indicates would be an appropriate answer (p.A59, LL.5 and 10). Paula's answers and the teacher's references to familiar experiences support the idea that a sensationalist view of explanation is conveyed in the dialogue with Paula. This view continues to be conveyed in the teacher's simple descriptive information about seeds with which the children are quite familiar (p.A59, LL.15-41).

The second contradiction of the view of science being conveyed is found on page A62. The teacher's question (LL.6-8) is a request for information about the seeds to be derived from observation of the illustration. The teacher further requires that a particular seed, of the milkweed plant, be identified (LL.11-19). This interchange conveys a formalist idea about observations. Immediately following this, the teacher's question requests a description of the milkweed plant (p.A62, LL.25-26) and is seen as a shift to a sensationalist view of explanation. This latter view continues to be conveyed by the discourse until page A64, line 33. At this point there appears to be a return to a formalist view of science since the teacher insists on certain answers and he later focuses on the formal characteristics of seed dispersal (p.A64, L.39 - p.A65, L.23). The implication in this last example is that such a review or confirmation of the discussion enables all of the pupils to understand the topic of dispersal.

## Contextual Support

The interview with the teacher supports the analysis carried out in this lesson and reveals that the focus of the lesson was to convey to the pupils appropriate science information which would clarify, as much as possible, the development and dispersal of seeds. The information communicated in the lesson is derived from the teacher's own biology background about which he claims to have a strong theoretical understanding (p.A150, L.38 - p.A151, L.6). This supports the main contention that a formalist view of science is being conveyed during the lesson. The reader is advised to examine the transcribed interview (Appendix B, p.A146 - p.A151) in order to understand the references made to the interview.

The teacher indicates that "almost all" the science information about plant pollination, fertilization, and reproduction had been presented during prior lessons in a structured, sequential manner (p.A146, LL.13-35). Moreover, since the pupils seem to understand so little about flowers and plants, he suggests that such information (as reviewed in the lesson) does help them acquire a better understanding of the processes involved (p.A146, LL.30-38). Then, the teacher's view about conveying appropriate science information, irrespective of the pupils' own understanding, supports the characteristics identified in the lesson discourse as conveying a formalist view of explanation.

The teacher had not intended to have the pupils memorize the science terms which appeared so frequently in episode II and episode III. Furthermore, the teacher indicates a preference for having the pupils "figure out the word" from the context of the lesson before providing the new term (p.A147, LL.23-30). This was clearly evident in the discourse by the way the teacher's questions were directed so that the terms such as pollination (p.A38) or dispersal (p.A50) were derived as rules. Thus, the teacher's view about the use of science terminology is consistent with formalist characteristics and supports the decision to include the use of such terms as an initial clue.

According to the teacher, the pupils had examined a tulip during a previous lesson, but more significant in terms of the kind of ideas conveyed to pupils, this examination of the reproductive parts of a flower was carried out after the science information was provided. The teacher indicated that this kind of observational experience clarifies the pupils' understanding of reproduction (p.A147, LL.1-17). This view includes the same characteristics of a formalist conception of observation as identified in the lesson discourse.

That is, the preconceptions of the teacher determine the kind of observations made by the pupils and, as noted by the teacher on page A146, lines 30-35, the experiences of the pupils are too limited for understanding seed development without such information.

During the analysis of episode III this investigator identified an interruption in the prevailing formalist view of science by brief sensationalist ideas being conveyed followed by the development of a via media view of explanation. This investigator also suggested that the use of an associated experiment might have further developed a via media view of science by linking experiential understanding with science knowledge. It is interesting to note that the teacher had planned such an experiment which he felt would help the pupils account for the effects of seed crowding on plant survival (p.A147, L.33 - p.A148, L.4). Thus the teacher does consider such pupil experiences to have some importance if these are carefully organized (p.A148, LL.25-32).

The interview, then, appears to support the analysis of this investigator that the dominant view of science being conveyed in the lesson is formalist, provided most strongly by explanation. The interruptions identified in the discourse as sensationalist appear to have no confirmation in the interview. Nevertheless, the initial clues as identified are being maintained. However, the brief identification of the development of a via media view (episode III) received some support from the teacher by his indirect and unsolicited reference to Michael who is able to put "things together very quickly", since "he's a very logical person" (p.A149, LL.38-40).

The discussion now turns to the presentation and coding of the clues identified in the discourse of this grade five science lesson.

## Identification of Initial Clues

Formalist ideas about explanation. In a classroom environment explanation of events involves both the teacher and the pupils in various types of interaction of which a question and answer format is only one example, but one which highlights the provision of ideas about science. Childrens' "explanations", however, are affected by their "restricted" view of the world. This refers to limited science knowledge expressed in abbreviated language. The intent to communicate a formalist view would consider such limitations a reason for the provision of science information by the teacher. It is the teacher, then, as the source of knowledge in the classroom, who determines what is said and by whom.

In this lesson, the formalist thrust is evident by the way the teacher builds logically sequenced explanations derived from his own theoretical background and what he considers to be acceptable. His preconceptions appear to limit the kind of explanation the pupils (are permitted to) provide, since what is known and expected is assumed to be of greater importance to the pupils' understanding than is their own interpretation and experience. This view is confirmed by the teacher in the interview. Such characteristics are consistent with Hanson's conception of explanation according to formalist thinking and also take into consideration the reality of elementary school science. With this in mind, these characteristics, which are identified in the lesson analysis, now become the initial clues representing formalist ideas about explanation.

Another clue, the use of scientific labels or terms, is not distinctly conceptualized by Hanson, but it is strongly manifest in this lesson. When considered in the context of formalist ideas being conveyed, it makes sense, at this time, to include it as an initial clue. However, this clue is listed separately from those which characterize the provision of science information since it is very possible for discourse to focus on the formal structure of scientific ideas without the use of such theory-dependent terms. The decision to include this clue will be better assessed when other science lessons are analyzed. Then the clarity and prevalence of this and other clues may be confirmed or denied. The characteristics which initially represent a formalist view of explanation are listed in Figure 6. The clues are coded F-c in the lesson analysis found in Appendix A (p.A31 - p.A68).

### Formalist Ideas About Explanation: F-c

The following clues reveal that formalist ideas about explanation are being conveyed during this science lesson.

| Characteristics | Examples from Discourse |
|---|---|
| T structures questions so that certain acceptable science information is provided which T understands and expects. | "But there is a reason why..."<br>"What has to happen once...?" |
| T's explanations include science information (rules/ definitions) logically derived from T's knowledge. Not in Ps' understanding or experience. | "...and then the seed case or shell begins to rot..." |
| Ps' explanations limited to science information (rules) given. Not related to Ps' personal experience. Confirm T's expectations. | "They're missing minerals."<br>"So it won't pop out of the seed." |
| T and Ps use scientific terms with no evidence of link between terms used and Ps' understanding of terms. | "photosynthesis"<br>"pollination" |

Figure 6. Characteristics of initial clues to formalist ideas about explanation.

Formalist ideas about observation. Although the major activity of this lesson is that of explanation, there are brief extracts which reveal what this investigator conceived as the provision of formalist ideas through observation. It is difficult to analyze these particular portions of the discourse since the "observations" are not carried out directly with concrete material or events. In the first episode, reference is made to observations carried out in previous lessons with the teacher soliciting particular observations which the pupils recall. In the last episode the observations are directed to illustrated seeds of which only a few are familiar to the pupils. Then, consistent with a formalist view of observation, the theoretical understanding set by the teacher as clues in the diagrams appears to be of greater importance in understanding seed dispersal than the pupils' familiarity, or lack of familiarity, with the seeds.

It has been mentioned that the interrelatedness of observation and explanation hinder clear identification and this investigator admits to encountering difficulties in the analysis of episode IV. Nevertheless, the impression that a formalist view is being conveyed is supported by the teacher's comments.

Figure 7, then, presents the characteristics of formalist ideas about observation which appear to be conveyed in this lesson. The clues are coded F-a in the lesson analysis which begins on page A31 in Appendix A.

## Formalist Ideas About Observation: F-a

The following clues reveal that formalist ideas about observation are being conveyed during this science lesson:

| Characteristics | Examples from Discourse |
|---|---|
| T structures Ps' observations so that certain information is perceived which T expects and considers important. | "There's a little clue there that gives it away." |
| Ps' observations are limited to and confirm expectations irrespective of Ps' own perceptions and experiences. | "...but I've never seen any leaves." |

Figure 7. Characteristics of initial clues to formalist ideas about observation.

Sensationalist ideas about explanation. In three episodes of this lesson, the ideas about explanation appear to move to the other extreme of philosophical thought. The impression that a sensationalist view of explanation is being conveyed is manifest by the way both the teacher and the pupils take into account the pupils' own familiarity with certain plants and seeds discussed in the lesson. The pupils' explanations (brief as they are) appear to involve sensory descriptions of what is obvious and familiar to them rather than theoretical interpretations ("sometimes there are three big branches"). The teacher does not focus on his preconceptions, rather, in the few instances identified, he expects the pupils to describe or account for events by referring to their own experiences ("How tall would you say the stem was?"). Generally, the language used by both teacher and pupil is simple and descriptive rather than theoretical. In fact this simplicity is found throughout the lesson except where scientific terms are stressed. Although this view of science is not supported by the teacher's comments in the interview, the lesson discourse appears to convey a sensationalist view of explanation which interrupts the formalist ideas in episodes II, III, and IV. The teacher, then, is apparently unaware that such views are being conveyed and he is thus unaware that conflicting ideas about science are being provided during the lesson.

The same characteristics of sensationalist ideas about explanation have been identified in the first lesson analyzed, thus giving support to those clues found in this lesson. The initial clues have been presented in Figure 4, page 103 and are not listed again. The clues are coded in the same way, as S-c, in the analysis of this lesson found in Appendix A starting at page A31.

Via media ideas about explanation. The third episode reveals an interesting development of a quite different view of science. In the discourse, the logical explanation given by two pupils shows that they have tried to apply the science information acquired during the lesson to the interpretation of a new, yet similar, event. Since the characteristics are not fully developed they are not consistent with a via media view of science as conceptualized by Hanson, even when considering the reality of elementary school. Nevertheless, this brief interaction conveys the beginnings or the development of a via media view of explanation.

It is significant to note that, in the interview, the teacher singled out one of the pupils, Michael, as capable of putting things together. This tends to support the suggestion that at least one of these pupils is developing his own view of science, different from that conveyed generally in the lesson.

The same development was seen in the first lesson analyzed but with a different characterization. Hence a new clue, as manifest in this lesson, is presented in Figure 8. It is given the same code, p-M-c, as in the previous lesson and refers to the clues which indicate that a via media view of explanation is developing. This code is found in the lesson analysis in Appendix A, from page A44 to page A45.

Via Media Ideas About Explanation: p-M-c

The following forerunner suggests that via media ideas about explanation are being developed during this science lesson.

| Characteristics | Hint from Discourse |
|---|---|
| Ps' explanations relate science information acquired in lesson to similar, new events. | "...all of the other coconuts have a head start and they grow..." |

Figure 8. Characteristics of a forerunner to via media ideas about explanation.

## Analysis of a Grade Four Science Lesson

This lesson is based on one from STEM Science, level 4 (Rockcastle et al., 1977, p.92-96), an elementary science textbook. The lesson has been separated into six brief episodes in order to make the initial analysis manageable, but of greater importance is that the divisions provide immediate recognition of the extent of the lesson as well as the specific topic of each episode. Prior to examining the lesson analysis the reader is strongly advised to read the complete lesson transcription, entitled Examination of Cells, found in Appendix A beginning on page A70. Without this review it is difficult to realize that, except for episodes I and VI and the change of topic, the other episodes follow the same lesson format. Nor would it be possible for the reader to recognize the characteristics of those clues which are identified as supporting the initial clues previously listed. This last point is the main thrust of this analysis and is the factor which determines the manner in which the analysis is presented.

Episode I: Review of Previous Study of Cells
(p.A70, L.17 - p.A74, L.4)

Episode II: Examination of the Onion Cell
(p.A74, L.19 - p.A78, L.9)

Episode III: Examination of the Cheek Cell
(p.A78, L.11 - p.A79, L.28)

Episode IV: Examination of the Blood Cell
(p.A79, L.30 - p.A82, L.5)

Episode V: Return to the Cheek Cell
(p.A82, L.26 - p.A86, L.4)

## Episode VI: Chicken Egg and Text Reading (p.A86, L.24 - p.A88, L.39)

An overview of the lesson dialogue discloses that formalist views about science are being conveyed. There also appears to be a distinct undercurrent of sensationalist ideas which are subdued by the prevailing formalist influence. Furthermore, the formalist views reveal new characteristics not yet manifest in previous lessons as well as some of the same characteristics as those already identified in Figure 6 (p.131 ) and in Figure 7 (p.133 ), thus supporting those initial clues. Additionally, the discourse reveals that observation is the major activity, but it is vicarious observation by pupils who have no direct contact with the plant and animal tissue being examined. The pupils have been provided with microslide-viewers, observation-enhancing instruments, each one of which is shared by four pupils. The use of viewers is not suggested in the teacher's edition of the textbook nor is such a device disallowed. Rather, the text recommends the use of elementary microscopes by the pupils and/or a microprojector for the class, as well as the preparation of slides by the pupils using available and familiar tissue. In this lesson the pupils are given commercially prepared slide sets for use with the viewers. Thus, use of these tools is meant to facilitate the pupils' observations of the features found in various plant and animal cells.

The discourse also indicates that a sensationalist view of observation is conveyed briefly, manifesting a characteristic not yet presented as a clue, as well as some of the same characteristics as those already identified in Figure 3 (p.101 ) thereby supporting those initial clues.

Since formalism appears to be the dominant view conveyed and since these characteristics have already been identified as clues, analysis of this lesson is not presented by individual episodes. Rather, only the first and last episode are considered separately with the others analyzed as a unit. The full coded analysis of the lesson is found in Appendix A from page A70 to page A90.

## Episode I

The discourse of this episode appears to convey opposing views of science. On the one hand the pupils are expected to respond to a scientific question for which the answer has no relation to anything the pupils have experienced. Then the pupils are asked to freely describe the cells which they observed, through the viewers, during the previous activity. The first suggests that a formalist view is being conveyed and the second implies a sensationalist view. The evidence follows:

> T: What do we mean when we say that cells are the building blocks of all living things? Exactly what do we mean?
> ...
>
> P: Cells are the building blocks, means that your body is made out of cells and the body of animals is made out of cells. (p.A70, LL.17-28)

This question appears to be a request for a theoretical explanation, not a mere description. The pupil's answer provides an explanation which is not at the level of theory nor is it a result of the pupil's experience, but it does suggest a recall of information. "Building blocks" and the meaning of the words in the context of the question may have been considered in a previous lesson, or a definition may have been provided, thus enabling the pupil to respond to the satisfaction of the teacher. The answer, however, does not appear to be a definition and the teacher follows with a few structured questions so that some clarification is achieved. The impression conveyed is characteristic of a formalist view. That is, scientific ideas can be "explained" by reference to science information that is known and expected.

Significantly, this brief request for a formal explanation is followed by a discourse which implies that even though cells cannot possibly be seen with the naked eye the differences between them can be recognized and understood by the use of micro-viewers.

> T: You can't see them. How do
> you know that they're there?
> How do you know they're there?
>
> P: You can magnify them.
>
> T: You can magnify them? OK.
> Are all these cells alike? (p.A71, LL.7-13)

Following this extract, the teacher solicits and accepts descriptions of the cells "seen" previously without providing the pupils with supporting science information (p.A71, L.23 - p.A72, L.32)

> T: Well explain something.
> How do some of them look like? (p.A70, LL.23-24)
>
> T: Looks like a rake? OK.
> What else?
>
> P: The muscle cells are long
> and thin.
>
> T: The muscle cells looked
> long and skinny. OK. Go on. (p.A72, LL.1-6)

These clues convey the impression that instruments such as the viewer, when used to extend normal visual acuity, enhance the pupils' observational skills so that "scientific" acceptability is based on their own perceptions and descriptions rather than on known science information. This impression appears to conflict with that seen on page A70, and is consistent with Hanson's view of the way sensationalist thinking affects the manner of carrying out scientific observation. The same idea is implied on page A72, line 35 to page A73, line 16, where the pupils are expected to associate the shape of muscle cells with their function. The distinct clue to the view that "seeing" the cells contributes to understanding their function is found in the following extract:

> T: ...What does it depend on, how the cell looks like? (p.A72, LL.36-38)
>
> P: There's certain things----
>
> T: So if something -- he's right. ...Remember the two types of muscle cells? One was from the arm or leg and the other was from the stomach. Everyone could tell it was a muscle cell because you said it was long and thin. Right? (p.A73, L.1 and LL.6-16)

The teacher's question suggests a request for an explanation based on the pupils' observations, but the important clue is "Everyone could tell..." the function of the cell because of its observed shape. It is possible that the teacher has dealt with such theoretical information in a previous lesson and he expects the pupils to recall the information while ignoring the pupils' lack of personal experience or understanding of "real" cells, in which case the teacher's question and comment could reflect a formalist view of explanation. However, the teacher does not follow a logical argument to explain the relationship between shape of cells and function of organs. Rather, the focus appears to be on what is observed and on understanding the function of cells because of these observations. This extract, then, supports the view that a sensationalist idea about observation is being conveyed.

It is interesting to note that the discourse which follows immediately after the above extract conveys a formalist view of observation. "Can you think of anything that is made up of only one cell?" (p.A73, LL.29-31) is a question which does not appear to depend on observation. Nor does the question request an account of a particular cell (p.A73, L.31 - p.A74, L.2). The teacher asks the pupils to recall what they observed in a prior lesson, which must have been discussed at that time. Furthermore, their answer must fit the teacher's conception of a single-celled living thing: "What am I thinking of?" (p.A73, LL.38-39). This extract is an example of the difficulty in distinguishing between observation and explanation activities in a lesson. The question requests an explanation yet the teacher refers to prior observations. The extract is analyzed as a formalist view of science being provided through observation because of the distinct focus on the pupils' observations. The teacher's understanding of what that observation should be appears to be of greater importance than the pupil's own comment "Amoeba" (p.A73, L.34) which (although unknown to the reader) is also found in the slide set examined by the pupils.

It would be appropriate to find out from the teacher what emphasis was given to observation of cells and to the provision of scientific information during the previous lessons. Such contextual information might clarify the apparent polar views of science being conveyed.

### Episodes II to V

The lesson continues to convey a characteristic formalist view. This is manifest by the manner in which the teacher directs the lesson activity so that only certain observations and information are acceptable, if those fit into the teacher's prior understanding and his expectations, irrespective of the pupils' own perceptions or their understandings. Moreover these same characteristics have already been identified as initial clues following analysis of the previous lesson. Consequently, what follows are examples of these formalist views found in the discourse of the lesson.

On page A74 and continuing to page A75, line 21, the teacher instructs the pupils to "Look at the boundary of the cell. That's all you're focusing on" (p.A74, LL.37-38). This is followed by more directions to "have a good look" (p.A75, L.5) and "another look" to be certain that all the pupils "see" two boundaries around the cell. Whether or not the pupils perceive cell "boundaries" in the slide is not under consideration, rather the teacher insists that this observation be made and he provides for it by his selection of the slide sets. (Although the structures visible in the photographs of the cells are not labelled, they are clearly identified by arrows which point to each major structure such as the nucleus or the cell wall.)

T: Two. You're sure. (P: Yes.)
Take another look. Everybody have
another look...You think two is
right eh? Two?

P: One.

T: One? Take another look at it.

P: Two. (p.A75, LL.10-16)

The pupils' problem of identification is compounded by the teacher's theoretical understanding of what should be seen. The importance given to the teacher's preconceptions suggests that a formalist view about observation is being conveyed.

A further example of the same kind of clue starts on page A77, line 39 and continues to page A81. Here the teacher reminds the pupils about observations made during a previous lesson regarding the presence of a nucleus in plant and animal cells. It is on the basis of this recollection that the teacher expects the pupils to determine whether or not they perceive a nucleus in the blood cell being viewed. This is explicitly revealed on page A79, line 27 until page A81, line 10.

T: Those are blood cells.

P: They have nucleuses.

T: Take a look at them.

P: They don't have a nucleus.

T: Take a good look. (p.A79, LL.31-35)

T: ...Now can you
find the nucleus in the blood
cells?

P: Yeah. Yes.

T: Where did you find the
nucleus? The white stuff?

Ps: Yes.

T: Ah. No. (p.A80, LL.5-12)

Irrespective of the pupils' own perceptions, that the blood cells "have nucleuses", the teacher continues to insist that looking at them will reveal the expected information. Significantly, this creates uncertainty and a change in the pupil's answer. Such changes have been identified previously with respect to the number of boundaries around the plant cell and may be the pupils' way of searching for the "right" answer -- one which confirms the teacher's expectations (p.A80, L.18 - p.A81, L.10). These characteristics are consistent with a formalist view of observation.

The teacher's continued request that pupils "take a good look" has been noticed above during the pupils' observation of the boundaries around plant and animal cells. The insistence that repeated observation (through the viewer) enables the pupils to find the number of boundaries or a nucleus may convey the message that the viewers are the key to making scientifically appropriate observations. This could leave an impression about scientific observation consistent with a sensationalist view, especially since the pupils are not informed whether they are observing red or white blood cells, nor are they provided with related science information. This is an example of the undercurrent of sensationalist ideas that has been suggested.

Without associated experience or knowledge about blood cells, the pupils have difficulty deciding what is significant -- their own perceptions or what the teacher claims they should perceive. "So how come we don't see that?" (p.A80, L.29) indicates that the pupils expect to be able to see the shape of the (red) blood cells as they have done with the other cells. It is entirely conceivable that the pupils are receiving such a conflicting set of ideas in the discourse: sensationalist in terms of the "value" of their own perceptions, and at the same time formalist because of the teacher's insistence that the observations conform to what is scientifically accepted -- "...no they don't have a nucleus" (p.A81, L.9).

There is further evidence in the discourse which suggests underlying sensationalist ideas while revealing the prevalence of a formalist view. When the pupils are directed to "explain the difference between an animal cell and a plant cell" (p.A83, LL.11-14) they are expected to "figure it out" by looking at the slides.

> T: No. No. Look at them!
> Look at them. You've got your
> microviewer. Look at them again
> (To one of Ps). You can't
> figure out what the difference
> is? (p.A83, LL.28-33)

The pupils, however, provide a description of what they perceive by recognizing the cell shape. This is an obvious answer derived from the chalkboard drawings, from the slides and from the prior discussions. Irrespective of the teacher's stress on recognizing characteristics which can be observed, he does not accept the pupils' answer based on their perceptions (p.A84, LL.5-17). His own preconception prevails. The pupils' perceptions, then, are governed or limited by the teacher's expectations.

> T: Animal cells do not
> have cell walls.
> ...now that you know, ...
> You will not find any one of those
> cells with a cell wall because
> they're animal cells, from the
> human body. OK? (p.A85, LL.15-22)

The interview with the teacher might provide further information about the purpose of the pupils' observations during this lesson and whether he planned the observations so that certain structures would be perceived.

Apart from the possible conflict between whether the view of science being conveyed is based on sensationalist or formalist thought, the discourse also reveals that the provision of formalist ideas alternates briefly between observation and explanation. This was also identified in the analysis of the second lesson and tends to support the contention made at the beginning of this chapter that distinguishing views of science through characterizations of one or other activity may be difficult. For example, at the beginning of page A79, the pupils are expected to see a nucleus in the slide of a cheek cell (p.A79, L.12) and immediately following this, they are asked whether "all cells have a nucleus" (p.A79, LL.20-21). The answer to such a general question cannot be derived by looking at a few slides. An acceptable response depends on science information which the pupils do not appear to have. Their "yes" and "no" comments suggest they are searching for an appropriate answer. But an answer to the subsequent question "Do plants and animal cells have a nucleus?" (p.A79, LL.27-28) does rely on the pupils' limited observations, since they have viewed a sample of both plant and animal cells.

From page A76 to page A78, line 25, there is evidence of the use of scientific terms when talking about the slides observed. Use of such terms, in the context of a formalist view of explanation, was revealed in the discourse of the previous lesson. It is difficult for the pupils to comprehend the "reality" of bacteria (p.A74) or cytoplasm (p.A77). Understanding these scientific terms requires theoretical knowledge which the pupils do not have. Seeing and recognizing what is called cytoplasm or a nucleus or a cell membrane has no relationship to anything the pupils perceive or have experienced. Hence they must rely on information provided by the teacher. In this lesson, such information is given by pointing out what the pupils should see during their observations. The pupils' problem in recognizing the cell "boundaries" has been examined, but a return to this issue in the discourse indicates that the pupils really do not understand what is meant, and assigning appropriate labels does not seem to help their understanding.

> T: Membrane? No.
>
> P: Well, what is a boundary?
>
> T: Well that divides one cell
> from the other. OK? What you're
> seeing is a number of cells put
> together. Can you see that?
> You saw them?
> ....
>
> T: OK. The outside
> boundary is very simple. It's
> called the cell --
>
> P: Boundary.
>
> P: Wall.

T: Cell wall. Good. (p.A76, LL.7-26)

Then on page A82 and on page A83 it is evident that the difference between cell wall and membrane is still not clear. In fact the confusion appears to be increased by the dialogue on page A84, line 30 to page A85, line 25, and later in episode VI on page A86.

The impression conveyed, then, is consistent with the formalist view previously suggested that the use of such scientifically acceptable terms may be the teacher's way of assuring that all pupils acquire a rule for understanding something with which they have such limited knowledge. In this lesson, however, the provision and use of scientific terms or rules is associated with the pupils' observations--what they should perceive and recognize as a particular cell structure.

It would be important to find out from the teacher what importance he places on the use of scientific terms and whether or not he provided pupils with any information about the cells being viewed.

## Episode VI

Analysis of this episode has been separated from the others only to identify the kind of confused message which is conveyed when science information, which is not fully understood by the teacher, is related to an object which is certainly familiar to the pupils.

The confusion begins on page A86, line 24: "An egg is a perfect way to describe the cell...". From this statement until page A87, line 33, the teacher uses the chicken egg as an example to (incorrectly) identify the parts of a cell considered during the lesson, even though page 94 of the textbook, to which the pupils are directed, contradicts the teacher's comparison. The teacher is probably unaware that he is conveying inaccurate science information to his pupils and it is not in the bounds of this study to pursue this point. The evidence in the lesson, however, appears to indicate that the teacher's concern is with assigning scientific labels to the structures of the egg which he knows the pupils are familiar with, irrespective of the fact that these labels cannot be applied to the egg in the manner he has chosen. The passage implies that a formalist view is being conveyed by the focus on recognizing the appropriate labels for certain structures that are observed.

The rest of this episode continues to convey formalist views of science with the focus on explanation. The evidence starts on page A88, line 4, and continues until the end of the lesson. The teacher appears to present carefully structured questions so that acceptable information is derived.

The interview with the teacher is now referred to in order to clarify the above analysis. This is followed by a presentation of new clues which are additions to the previously noted initial characterizations.

## Contextual Support

The interview with the teacher provides support for the suggestion made in the lesson analysis that underlying the prevailing formalist view of science there is a distinct influence of sensationalist ideas. The reader is advised to examine the transcribed interview which is found in Appendix B (p.A152 - p.A158) in order to recognize the conflicting ideas which are revealed and which will be referred to.

The teacher indicates that the focus of the previous lessons was for the pupils to "have a good look at" certain cells in the slide because "that's what cells are" (p.A152, L.35). He contends that this observation would enable the pupils to recognize the structure and different appearance of the cells (p.A153, LL.30-31) as well as their function (p.A154, LL.4-14). The teacher also reports that he did not tell the pupils what should be perceived, nor does he expect them to remember the terms given to the structures identified. Rather, he is convinced that the pupils' observations would generate an understanding about the function of the particular cell observed (p.A154, LL.2-7). This kind of emphasis reveals the influence of sensationalist thinking about scientific observation, the characteristics of which are consistent with Hanson's view. In fact this is the impression conveyed briefly in the first episode of the lesson. Nevertheless, this view is contradicted in other comments by the teacher, and more significantly, the contradiction is found in the discourse of the lesson (except in episode I).

During the interview, the teacher states that discussion about the cells, provided during previous lessons, probably included rules or definitions about those cells (p.A152, LL.22-26). The teacher feels that the provision of "more information" helps the pupils understand what they are observing with the viewers (p.A154, LL.16-31) and he submits that the observations do serve to corroborate the information provided during the discussions (p.A157, LL.1-6).

There is an apparent contradiction between what the teacher perceives as the value of the pupils' observations and what he says about the need for information to help the pupils understand what they observe. Further contradictions surface when he indicates that he expects the pupils to report "Just what they had seen. No more" (p.A155, L.16), but the evidence in the lesson reveals that he accepts what pupils perceive only if these observations confirm his own understanding. In fact, in order to be certain that particular structures would "stand out" he selected the slides on the basis of their clarity and ease in locating the structures he felt were more important (p.A154, LL.37-40). These formalist views about observation confirm the characteristics identified in the lesson analysis. Further support is given by the teacher's comment that, since not all children "have really grasped what you are trying to get at"(p.A156, LL.17-19), they need more time with the viewers and more information about the structures, information which he wants them to acquire (p.A155, L.30).

The interview appears to reveal a conflict in the teacher's own view about scientific inquiry although he is unaware of the kinds of ideas being conveyed. However, the purpose of this study is not to judge or label teachers as holding one or other view of science. Rather, the purpose is to characterize the messages about science being conveyed during a lesson. The interview with the teacher appears to support the analysis that a formalist view of observation is conveyed in the discourse with some evidence of sensationalist ideas both obvious and underlying the prevailing formalist view of science. The teacher's comments also suggest that this dominance of one view over another may have been reversed in a prior lesson.

## Identification of Initial Clues

The analysis reveals an important issue about the kind of messages pupils may receive during a science lesson. In this lesson there is evidence of a conflict of views about science, even though one view (formalism) appears to dominate the other (sensationalism). Conflicting "meta-learnings" (Schwab, 1962, p.45) have the potential of confusing pupils about science in the short or long term. (This instance shows the potential usefulness of the scheme as a supervisory tool since the teacher is apparently not aware he is generating conflicting messages.)

Contradicting views about science have been identified in the second lesson analyzed, but in that lesson, as in the first episode of this lesson, characteristics of both sensationalist and formalist ideas alternate in the discourse. In the other episodes of this lesson the utterances of both the teacher and the pupils provide evidence that the opposing ideas are subdued and underly the prevalent formalist view of science being conveyed.

Sensationalist ideas about observation. A sensationalist view is manifest in the first episode where the pupils are expected to describe the cells they examined in a previous lesson. Although there is no direct experience with the tissue being observed, the "onion" and "cheek" are known to the children but not in the context of "cells". A similar kind of situation has been discussed in

Chapter IV (p. 51 ). In that example Hanson (1969) refers to the "sense of floundering" felt by freshman students when they are expected to observe biological tissue never seen or experienced before. In this grade 4 lesson, younger students are expected to recall observations made of slides of tissue which they could not possibly identify or distinguish without the provision of scientific information. Nevertheless, the teacher provides no additional information to support their observations while he solicits and accepts sensory descriptions of the cells perceived with the viewers. Recognizing that the pupils' activity in this episode is a discussion about prior observations, the focus is on what is understood because of their perceptions and does not detract from the evidence given. That evidence suggests that a sensationalist view of observation is being conveyed, briefly, in episode I. Significantly, the characteristics identified are the same as those conceptualized by Hanson and those identified in the first lesson analyzed, thus supporting the initial clues found in Figure 3, (p. 101). These same clues are not presented again in this section.

However, this same episode exposes a characteristic of sensationalist thought which has not been revealed in the previous lessons analyzed. The message conveyed by this clue implies that observation of science material is expected to generate an understanding of that material, which in this lesson refers to the function of animal cells (p.A72 - p.A73). The characteristic of this new clue is presented in Figure 9 and is coded S-a. This is the same code as previously assigned to clues which characterize sensationalist ideas about observation. The clues are noted in the lesson analysis found in Appendix A beginning on page A70.

### Sensationalist Ideas About Observation: S-a

The following clue reveals that sensationalist ideas about observation are being conveyed during this lesson:

| Characteristics | Example from Discourse |
|---|---|
| Ps' observations are expected to generate an understanding of the science material being examined. | "everyone could tell it was a muscle cell because you said it was long and thin." |

Figure 9. Characteristics of an initial clue to sensationalist ideas about observation.

Formalist ideas about observation. The lesson discourse exposes a set of clues, the characteristics of which are consistent with Hanson's conception of formalist thought. Moreover, these characteristics also support those which are found in the previous lesson analysis. Throughout the lesson, the teacher appears to structure the pupils' activity so that only certain observations are made. These observations, then, are expected to confirm the teacher's expectations and his own scientific understanding of what should be perceived irrespective of the pupils' own perceptions, and irrespective of the underlying impression that their observations can generate an understanding of science. This is evident when the pupils question their inability to see the shape of the red blood cells, or the lack of a nucleus in these cells, or two boundaries around a plant cell. The teacher's reaction supports the impression that formalist views are being conveyed: "Yes, there are two boundaries" (p.A75, L.19) and "...no, they don't have a nucleus" (p.A81, L.9). In order to assure that scientifically appropriate observations are made, the teacher provides the pupils with those slides which clearly reveal the structures he wishes them to perceive. These same characteristics which reveal that a formalist view of observation is being conveyed in the discourse of this lesson have already been identified in the previous lesson and the initial clues are listed in Figure 7 (p. 133 ). Consequently, the same clues are not repeated here; however, there is evidence of two new clues which have not yet been identified as revealing a formalist view of observation.

In the analysis of the previous lesson the use of scientific terms was exposed as a clue applicable to a characterization of a formalist view of explanation. This characteristic is manifest again in this lesson in the context of the pupils' observations. This reveals the relatedness of characteristics of clues which identify different activities within the same view of science. Even though the teacher reported that he did not intend that the pupils remember the scientific labels for the structures, the discourse reveals that he himself referred to these terms and he did expect the pupils to use the terminology when referring to their observations of the cells. Moreover, the pupils do not appear to see a relationship between what they perceive (as a boundary, or "white stuff", for example) and the application of a scientific term to the structures, except as defined labels ("Well, what is a boundary?" (p.A76, L.9)). This characteristic, then, can be included as an additional clue for the identification of formalist ideas about observation.

The discourse also reveals evidence of the pupils' altering their own perceptions when they realize that these do not conform with those the teacher expects. This is found in the extract about the number of "boundaries" around the cell (p.A75) and again regarding the presence of a nucleus in a red blood cell (p.A79). In both of these instances the change of answer may be due to the conflicting message being received by the pupils. Which is more acceptable, what they themselves perceive or what the teacher wants them to "see"? This characteristic, then, is included as a new clue for the identification of formalist ideas about observation.

As new clues, these are characterized in Figure 10 and again given the same code, F-a, as the previous clues exposed as conveying formalist ideas about observation. All of these clues are identified in the analysis of the transcribed lesson in Appendix A, starting on page A70.

Formalist Ideas about Observation: F-a

The following clues reveal that formalist ideas about observation are being conveyed during this science lesson:

| Characteristics | Examples from Discourse |
|---|---|
| Ps expected to use scientific terms when referring to observations with no evidence of a link between what Ps perceive and their understanding of the terms. | bacteria, nucleus<br>"All of this material inside... called cytoplasm." |
| Ps' observations may be altered to confirm what is known and expected. | "No, they don't have a nucleus."<br>"One? Take another look." |

Figure 10. Characteristics of initial clues to formalist ideas about observation.

Formalist ideas about explanation. The discourse reveals a few characteristics which suggest that a formalist view of explanation is being conveyed in the first episode and again in the last episode. In episode I, the teacher's questions request theoretical explanations rather than a description of events observed. The pupils' comments are derived from prior science information rather than from their own perceptions or experience. In the last episode, the teacher structures his questions so that certain information is provided -- information which he considers to be acceptable and important.

These characteristics have already been identified in the analysis of the second lesson and can be found in Figure 6 (p.131 ). Hence these clues are not listed again, but they are noted in the analysis of the transcribed lesson (Appendix A, starting on p.A70) by the code F-c.

## Summary

The discussion in this chapter included two important activities of the study. The beginning of the chapter examined the usefulness of interviews with the teachers in clarifying questions of context when analyzing lesson discourse. Then the collection, presentation and coding of the data was described. This was followed by the major argument of the chapter: the analysis of three science lessons and the derivation of the initial clues which, later, become categories of the analytical scheme.

Analysis of the science lessons revealed that it is possible to characterize the kinds of ideas about science being conveyed during elementary school lessons. It was further evident that such ideas are provided through varied activities and can be exposed by analysis of the lesson dialogue. Moreover, the characterizations of these ideas are consistent with those conceptualized by Hanson, as translated to the experiential and developmental level of elementary school children.

The discourse of the lessons revealed that sensationalist ideas about observation, investigation (experiment), and explanation, as well as formalist ideas about observation and explanation can be identified. It was further found that clues which convey via media ideas about science are not evident in the discourse of the three lessons analyzed. A few characteristics of such ideas, provided through explanation, were identified as developing in the first and second lessons analyzed. Following analysis of each lesson, the characterizations of the ideas about the nature of science were presented as a set of initial or "untested" clues.

In Chapter VI these initial clues are summarized as a seven-category analytical scheme. The clues are then tested for their clarity by application of the scheme to a grade six science lesson by the investigator. This reveals new clues which are incorporated into a revised nine-category analytical scheme. Finally, assessment of the clarity of these clues, by two independent judges, is discussed.

## Chapter VI

## THE ANALYTICAL SCHEME

### Introduction

In the previous chapter an initial clue structure was derived which characterizes the views of science provided in the discourse of three elementary science lessons. The present chapter will discuss the coherence of these clues and the decision to retain and to present the two kinds of "descriptors", revealed in the clue structure, as the categories for the analytical scheme. (That is, one kind of descriptor pertains to the view of science, while the other refers to the classroom science activity.) The investigator's application of this analytical scheme to a grade six science lesson confirms the recognizability of some clues and the need to modify others. Most important, in terms of the study, the lesson analysis exposes new clues not previously identified. The new clues and the modified clues are then incorporated into a revised, nine-category analytical scheme. The chapter concludes with a discussion of the assessment of the clarity of the clues by two independent judges who applied the revised scheme to the same grade six science lesson analyzed by the investigator.

### Categories of the Scheme

The initial clue structure presented in Chapter V revealed characteristics which are reviewed here since these influence the method of establishing the categories of the scheme.

The clues derived from analysis of the three science lessons exhibit a repetition of characteristics associated with each of the polar views of science irrespective of the science activity engaged in. That is, the clues which identify sensationalist ideas about science, for instance, appear to be patterned and repetitive whether the activity is one of scientific observation or explanation. Such patterning is evident when a comparison is made between the characteristics found in Figure 3 (p.101) and Figure 4 (p.103). The notable difference between the clues is reference to the activity: observation or explanation. In the same way, the characteristics of clues which identify formalist views of science, found in Figure 7 (p.133) are repeated in the clue structure of Figure 6 (p.131). It is interesting to note that this relationship has already been mentioned in the lesson analyses as creating difficulty in distinguishing between these activities. However, such a relationship between the clues for identifying the development of a via media view of science is not yet evident since only one set of clues has been revealed -- the development of via media ideas about explanation. Nevertheless, since a relationship is found in both polar views, it seems reasonable to assume that the same kind of coherence would be evident in the clues which characterize the development of via media ideas about experiment and observation. Recognizing such relationships is a factor in deriving some of the "unexposed" categories of the scheme, referred to later in the chapter.

Because of the duplication of characteristics, it would be less demanding (for the purpose of lesson analysis) if the characteristics in the analytical scheme were consolidated so that only the views of science are identified. However, the purpose of this study is to distinguish between as wide a range as possible of ideas being conveyed.

This can best be fulfilled by a scheme which categorizes not one, but two kinds of "descriptors" regarding scientific inquiry, as does Hanson, thereby maintaining the integrity of his conceptualization. The descriptors or categories, then, distinguish between views of science and also distinguish between classroom activities. Retaining the activities as individual categories, with their specific characteristics, provides the analytical scheme with greater scope and sensitivity for identifying the manner in which different views of science are being conveyed.

Analysis of the science lessons revealed that only one or two clues were needed to identify that a particular view of science was being conveyed in a portion of discourse. In fact, the initial clue structure was derived by bringing together such individual clues which characterized a view of science. The analytical scheme, then, will also indicate that only one or more of the clues of a category need be evident in order to reveal that a view of the nature of science is provided for in the discourse of a lesson. The clues found in the initial clue structure are now summarized to become the categories of the analytical scheme. In order to achieve clarity and coherence in the categories, some clues may be reworded, clues may be consolidated, or the order of the clues may be changed from that found in the initial clue structure.

### Sensationalist Ideas About Science

The initial clues found in Figure 3 (p.101) with the additional clue which is listed in Figure 9 (p.154) now become one category of the analytical scheme for the identification of sensationalist ideas about observation. The clues found in Figure 2 (p. 99) become a second category for the identification of sensationalist ideas about experiment (investigation). Since a relationship has been found between the characteristics of the initial clues provided by the science activities, the clues in this category are extended to include those which correspond to the other categories of the same view of science. These added clues are presented in "script" to affirm that they are not derived directly from discourse. A third category identifies sensationalist ideas about explanation. The clues for this category are summarized from Figure 4 (p.103). Then, the first three categories of the analytical scheme which reveal that sensationalist ideas about science are being conveyed in the discourse of a lesson are presented in Figure 11. These categories retain the same code as found in the initial clue structure.

## Formalist Ideas About Science

A fourth category of the analytical scheme is the identification of formalist ideas about observation, derived from the clues found in Figure 7 (p.133) and in Figure 10 (p.157). The clues listed in Figure 6 (p.131) represent those characteristics which reveal a formalist view of explanation. These clues become a fifth category of the scheme and both categories retain the same code as assigned to the initial clues.

Analysis of the three lessons did not reveal clues for the identification of a formalist view of experiment (or investigation). However, because of the relationship which has been found between the characteristics of the clues which reveal the polar views of science, it can be assumed that clues which identify a formalist view of experiment would exhibit the same kind of characteristics as those of observation and explanation. On the basis of this assumption and to maintain the consistency of the scheme, clues which would most likely expose a formalist view of experiment are suggested by this investigator. These clues represent a sixth category of the scheme and are presented in a "script" type, again to indicate that they are not derived from lesson analysis. This category is given the code F-b, consistent with the other codes of the scheme. Then, the clues which reveal a formalist view of science are found in Figure 12 as three more categories of the analytical scheme.

### Via Media Ideas About Science

The discourse of the three lessons analyzed did not manifest characteristics consistent with a via media view of science, although there was evidence which revealed the development of such a view in the discourse of the first and second lessons. In order to maintain the integrity of Hanson's analyses, it would be advantageous to have a set of clues available for recognizing via media views which are conveyed in elementary lessons. However, the limited science knowledge, experience and understanding of elementary school pupils might preclude the possibility of "seeing" such views in "full flower" in lesson discourse. Then it seems reasonable to accept and to include, as categories in the analytical scheme, the clues to the development of this view of science which have been identified. At this time the only set of clues identified are those which characterize the beginnings of a via media view of explanation, but no clues have yet been found which reveal this view of science provided through experiment or observation.

Without deriving these clues directly from analysis of discourse, this investigator could suggest the kind of characteristics which would be present on the basis of those already revealed as conveyed through explanation (as was done for a formalist view of experiment). However, it was decided that a single set of clues is insufficient data from which to extrapolate two more categories. Consequently, at this time, only one category of clues, as forerunners to via media ideas about explanation, is presented in Figure 13. These clues are derived from those already identified in Figure 5 (p.104) and in Figure 8 (p.135). The code for this category is the same as that given to the initial clues, p-M-c.

The clues found in the initial clue structure have been summarized to comprise a seven-category analytical scheme. The scheme is now applied to a grade six science lesson. This analysis confirms some of the clues and reveals new clues not previously exposed.

## Sensationalist Ideas About Science

Elementary science lesson discourse conveys sensationalist ideas about science, if one or more of the following clues are revealed:

| S-a Ideas About Observation | S-b Ideas About Experiment | S-c Ideas About Explanation |
|---|---|---|
| T solicits, accepts as much sense-data information as possible, without telling Ps what to look for. T expects that observations may reveal something important. | T solicits, Ps freely gather as much sense-data information as possible from various tests. | T's questions may use "why", "explain", or "how do you know" in same context as describe. Requires information from Ps' own experiences. |
| Ps are preoccupied with random observations. They perceive what is concrete and obvious through the use of their senses. | Ps carry out investigations in a random manner without T direction about procedure or results to expect. | Ps answer or explain with sense-data descriptions of what is concrete and has been experienced. |
| T does not provide scientific information about material being observed. T expects that observations may generate an understanding about the material being examined. | *T does not provide scientific information about the material being investigated.* T expects that investigation and results may generate important information. | T does not provide scientific information in explaining events experienced. |
| Ps and T talk about observation using descriptive non-scientific language. | *Ps and T talk about investigations and results using descriptive, non-scientific language.* | Ps and T use descriptive, non-scientific language to explain events. |

Figure 11. Analytical Scheme. Sensationalist ideas about science.

### Formalist Ideas About Science

Elementary science lesson discourse conveys formalist ideas about science, if one or more of the following clues are revealed:

| F-a Ideas About Observation | F-b Ideas About Experiment | F-c Ideas About Explanation |
|---|---|---|
| T directs Ps' observations so that certain information is perceived which the T expects and considers important. | *T directs Ps' investigations so that they are carried out in a particular way, according to the T's understanding of the problem.* | T directs questions so that science information is provided which T considers acceptable. |
| Ps' observations limited to and confirm expectations irrespective of their own perceptions or experiences. | *Ps' investigations follow instructions given. Data gathered by Ps confirm T's expectations and preconceptions.* | Ps' explanations limited to science information (rules) given. Not related to their experiences. Confirm T's expectations. |
| Ps' observations may be altered to confirm what is known and expected. | *Ps may talk about changing results or repeating an experiment if results contradict expectations.* | T's explanations include science information (rules, definitions) derived from T's knowledge not in Ps' understanding or experience. |
| T and Ps use scientific terms when referring to observations with no evidence of a link between what Ps perceive and their understanding of the terms. | *T and Ps may use scientific terms when referring to procedures or results. Ps may not understand meaning of terms in context of investigation.* | T and Ps use scientific terms with no evidence of a link between terms used and Ps' understanding of terms. |

Figure 12. Analytical Scheme. Formalist ideas about science.

## Via Media Ideas About Science

Elementary science lesson discourse is developing via media ideas about science, if one or more of the following clues are revealed as forerunners:

p-M-c
Ideas About Explanation

---

Ps' explanations relate science information acquired in lessons to similar, new events.

T's explanations relate science information that is known with Ps' own understanding and experiences.

T and Ps use complex, scientific vocabulary when explaining events.

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Figure 13. Analytical Scheme. The development of via media ideas about science.

## Application of the Analytical Scheme

The following analysis serves two purposes. The first is application of the analytical scheme to the discourse of a grade six science lesson. This application is meant to assess the clarity of the derived clues for distinguishing between the different kinds of ideas about science being conveyed, and to decide whether there is a need to revise one or more of the clues which comprise the seven categories of the scheme.

A second purpose is to continue reflexively using Hanson's three conceptions of science as a guide to possible "characterizations" of scientific ideas in the context of classroom reality. This reflection may expose new clues not yet identified for inclusion in the analytical scheme, such as those which characterize the provision of a via media view of observation and experiment.

The science lesson is one of a series from the Elementary Science Study unit Batteries and Bulbs (E.S.S., 1968). The discourse has been divided into five episodes to facilitate the analysis and to separate classroom management aspects of the lesson from the discourse being analyzed.

| | |
|---|---|
| Episode I: | Review of Previous Activity (p.A93, L.33 - p.A97, L.5) |
| Episode II: | Experiment with Light Meter (Two groups of pupils.) (p.A97, L.7 - p.A103, L.24) |
| Episode III: | New Experiment (One group of pupils.) (p.A104, L.6 - p.A108, L.20) |
| Episode IV: | Discussion of Results (p.A108, L.21 - p.A113, L.35) |
| Episode V: | Recording of Results (p.A114, L.20 - p.A116, L.21) |

It is recommended that the reader examine the transcribed and analyzed lesson found in Appendix A (p.A92 - p.A117) prior to reading the analysis. This will enable the reader to understand the context in which the new clues are identified in the discourse and to recognize the categories of the analytical scheme to which the analysis refers.

The seating of the pupils in groups of four, in a very spacious classroom, created difficulty in achieving a clear recording of pupil - pupil interactions. By moving the recorder from one group to another, it was possible to capture and subsequently transcribe the dialogue between the pupils in three groups (see episode headings). There was no difficulty recording and transcribing the teacher's instructions and comments to the class.

An overview of the lesson reveals that the activity focuses on both experimental inquiry and explanation, but more significantly, characteristics of clues to the development of via media ideas about experiment are identified. These new clues, not yet found in previous lessons analyzed, are revealed in two episodes, while the clues which characterize the development of a via media view of explanation are found in three other episodes. Thus each of the five episodes reveal that a via media view of science is being conveyed, in some way. Additionally, new clues which characterize a formalist view of experiment are briefly identified.

The lesson is analyzed by episodes in order to reveal the characteristics of the new clues in the context of the lesson activity and, in particular, to point out how the pupils in three different groups have become aware of a via media view of science being developed. The analysis, then, focuses on the new clues with attention being given to shifts in the view of science being conveyed. The analyzed and coded lesson is found in Appendix A beginning on page A92.

### Episode I

The beginning of this episode reveals that a sensationalist view of science is being conveyed and provided through experiment and explanation. In response to the teacher's questions, the pupils talk about the experimental activity of a previous lesson by reflecting on their own involvement and familiarity with the materials used. This is manifest by the pupils' descriptions of their investigations. Examples of such a sensationalist view of experiment are found on page A93, lines 34 to 46 and again on page A94, lines 21 to 42.

The teacher's question, directed to Claudia, appears to be a request for an explanation: "and what did that light meter do for us?" (p.A94, LL.9-11) Claudia's description of the light meter (p.A94, LL. 12-20) indicates that she is familiar with the activity and the results through her own concrete experiences with both the light meter and a circuit. The teacher's question and Claudia's response are examples of the influence of sensationalist ideas conveyed through explanation. When the teacher asks the pupils what difference was found between the two kinds of bulbs (p.A95, LL.4-6 and 13-17) she is again requesting an explanation based on the childrens' own experience. Even though Richard provides a sensory description of his observations (p.A95, LL.9-11), the teacher repeats her request for an explanation.

T: And how did we know the
difference? There's
nothing written on the
bulb, but how do we know
which one's which? (p.A95, LL.13-17)

The pupil's subsequent response is again a description of sensory information resulting from observation during the activity.

P: Miss, in the PB bulb
the little thing is trans-
parent and the WB bulb
the little thing inside is pink. (p.A95, LL.18-21)

The implication here is that the colour of the separator accounts for the difference between the bulbs and the pupils' own experiences with the different bulbs appear to have helped them recognize this. The idea conveyed by this interaction also appears to reflect a sensationalist view of explanation, the clues of which are already found in the analytical scheme. However, the teacher's requests and the pupils' responses present examples of the difficulty which may be encountered in distinguishing between the activities through which the sensationalist ideas are being conveyed; explanation because of the type of question asked and answer expected, or observation because of the answer accepted (apparently). The discourse, however, indicates that the teacher's questions focus on explanations: "How do we know?" rather than on: "What did you see?" Hence, the extracts are analyzed as conveying sensationalist ideas about explanation.

A shift in ideas about science appears on page A95, line 22 and continues to page A96, line 3. In this extract the teacher prefers the term "glass separator" to the pupils' term "bead". This insistence on a particular scientific term suggests that a formalist view of explanation is being conveyed. However, the pupils do appear to understand the meaning of the term "separator" and the context in which it is used. This is evident by the teacher's reference to the word "separate" (p.A95, L.36 - p.A96, L.3) and previous to this, the teacher relates separator to light intensity (p.A95, LL.22-23). This would imply that via media ideas about explanation are developing in this part of the episode. Furthermore, the dialogue which follows on page A96, line 28, to p.A97, line 6 continues to develop the same views of science. Not only are scientific terms used with understanding, but also Peter's comment indicates an attempt to account for the activity by drawing on his experience with and understanding of circuits.

> Peter: We used one or two batteries and we took our fahnestock clips and we made a series of battery holders and to see if the bulbs could light if they were connected together. (p.A96, LL.28-34)

## Episode II

This episode continues to expose the development of via media ideas about science that are first seen at the end of episode I. However, in this episode these views are provided through experiment and represent new clues, not yet identified, to be included as a category of the analytical scheme.

The teacher's request that the pupils make a simple circuit *again* indicates that it is not a new activity for them (p.A97, LL.7-9). Moreover, to avoid aimless activity, the teacher provides the pupils with guidance or a framework for their experimental activity by directing them to relevant aspects of their investigation.

> T: ... make sure
> your lights are all in a
> series. Now, what we want
> to find out today is the
> light, okay, the intensity
> of light. See if they all
> light the same. See if
> there's a difference. (p.A97, LL.23-30)

Rather than expecting the pupils to set up a series circuit and to randomly collect as much data as possible, which would be consistent with a sensationalist view of experiment, the teacher provides some order to the pupils' inquiry. By helping them set up their circuit without telling them how to do so, she is relying on their prior experiences and understanding of a circuit (p.A97, L.35 - p.A98, L.3). She further guides the pupils to relevant results without informing them what those results should be: "see if they all light the same. See if there's a difference" (p.A97, LL.28-30). Such guidance is repeated again on page A99, lines 26-35, where the teacher reminds the pupils about the purpose of their activity. The teacher, then, is establishing the parameters of the pupils' investigations with the success of the inquiry dependent on the pupils' own experiences and their understanding of circuits.

If we accept the notion that elementary school pupils do not have the depth of experience and knowledge of scientists, then it is reasonable to suggest that these extracts reveal the development of via media ideas about experimental inquiry. In the middle of this teacher guidance there appears a single comment which initially suggests that a sensationalist view of experiment is being conveyed. The teacher implies that the pupils are able to "find out why" or to account for the difference in light intensity by means of the test results (p.A97, LL.31-33). This is characteristic of a clue which considers that experimental results can generate important information about the problem being investigated. Nevertheless, when taken in the context of the whole extract, this comment is seen to be the teacher's way of guiding the pupils' activity. By relying on their prior experiences with and understanding of circuits, she expects the pupils to "build" their own reason for the difference in light intensity, as a result of their investigation. (It is interesting to note that the teacher's comment could also refer to explanation and is another example of the difficulties which are encountered in distinguishing between classroom activities referred to in a discourse.)

The rest of the episode contains the dialogue between the pupils of two different groups. On page A98 to page A99, line 35, the interaction between four girls may, at first reading, suggest that they are engaged in random activity, without direction or purpose. However, there is evidence in the discourse that the girls' activity is not random -- first, because of the teacher's initial guidance, and second because some of the pupils' comments suggest that they know how to proceed and are doing so, as a group.

For example:

> $P_2$: Yes, but you have to connect them like this. This one wasn't there. You have to put them all in with this. (p.A99, LL.7-10)
>
> $P_4$: Now, where's our battery? (p.A99, LL.20-21)

The dialogue of a second group of pupils, four boys, begins on page A100 and continues to p.A102, line 31. Apart from their dialogue, which includes some contradictions to be dealt with shortly, the investigator's notations of the boys' activity supports the view that their investigations are not random. The notations are found on page A99, lines 37-40, again on page A101, lines 31-33, and on page A102, lines 30-31. Rather than approaching the problem with an "open and unbiased mind" (Hanson, 1969, p.249), as they would under the influence of sensationalist ideas, both groups of pupils are demonstrating an awareness of the set provided by the teacher and they are using their own prior experiences with a circuit and their understanding of a light meter to carry out their investigation. These characteristics represent a development toward a via media view of experimental inquiry.

Notwithstanding the above, the discourse between the group of boys seems to be interrupted by a shift of ideas. This is seen on page A100, lines 15-26, and on page A101, lines 1-8. Although there is nothing in the teacher's comments to indicate that a particular result is expected with the light meter, this group of boys believe that their findings must meet certain expectations. That is, they should "be all the same" unless one is "wrong".

> $P_1$: Let me check. Four.
> This is at 4, here.
>
> $P_2$: 4, 4, 3.
>
> $P_1$: It should be all the same.
>
> $P_2$: Yeah, it should be.
>
> $P_3$: These two are 4 -- unless
> this one's wrong. (p.A100, LL.20-26)

The idea that a uniform result is expected is a characteristic of Hanson's view of experimental inquiry under the influence of formalist thought, an impression about science which these pupils might have acquired from the teacher in a prior lesson. However, one of the boys ($P_4$) suggests the "cause" of the discrepancy may be the different thickness of the various light meters and he suggests that the group use a single meter to take their reading of the light intensity.

P$_4$: Check it all with the same one. Maybe one of them has thicker paper than the other you know. (p.A100, LL.27-30)

This pupil, by referring to the lack of standardization of their "equipment", demonstrates an understanding of the purpose of the light meter in the context of their experiment. This comment is an example of his "uptake" or awareness of the development of a via media view of experiment. He continues to support this view when he expresses disagreement with his three buddies when they decide to report the same light meter reading, irrespective of their varied results (p.A100, L.33 - p.A101, L.20).

P$_3$: Yeah, all of them are 4.

P$_4$: You could see it at 5.

P$_3$: Okay, write it down.

P$_4$: They're all at 4?

P$_2$: Yup. All of us had 4, Miss, exactly. (p.A101, LL.3-8)

T: You didn't find any difference.

P$_2$: Nope. No, Miss.

P$_4$: The power's not the same in back there. (p.A101, LL.13-15, 19-20)

Had the pupils been carrying out a random activity without the benefit of the teacher's prior framework, and had the pupils reported their varied results with the light meter, the discourse would be considered to convey sensationalist ideas about experiment. However, by altering the results of their investigation to confirm what they believe is expected, the three boys demonstrate a formalist view of experiment in this particular dialogue, even though their activity and comments prior to and subsequent to this extract reveal the development of a via media view of experiment.

## Episode III

The pupils have been provided with non-insulated copper wires and the teacher expects them to set up "another type of circuit". A rapid reading of the teacher's instructions (p.A104, LL.6-31) could give the impression that sensationalist ideas about experiment are being communicated. The pupils are asked to "find out" how to connect their circuit in a different way and they are not told why the uncovered copper wire has been provided. Such imprecise instructions appear to suggest approval of random activity, with no particular results expected. However, a close examination of this same extract reveals otherwise. Clues are evident which clearly indicate that a via media view of experiment is being developed.

> T: ... You
> have to try to make another
> type of a circuit. And
> this circuit ...
> will not be in series like
> we've done before. You're
> gonna try to connect your
> bulbs in different areas,
> but always going back to
> the power. (p.A104, LL.13-22)

The teacher's instructions about what the new circuit should not be helps the pupils organize their experimental activity (p.A104, LL.34-45). Without being told what the resulting circuit should look like: "I don't care how you connect it up" (L.42), or how to use the copper wire, the pupils are expected to rely on their prior experiences and their understanding of the activity to create a circuit in which "the bulb has to go ... back to the battery" (p.A104, L.25). Aimless activity is avoided rather than encouraged.

A further characteristic of the development of a via media view of experiment is the free use, by teacher and pupils, of scientific vocabulary. This is evident throughout the episode and suggests that the pupils understand the meaning of these terms in the context of electrical circuits.

The rest of the episode turns to the dialogue and activity of a third group of pupils. Although the comments of the boys (p.A106, LL. 6-21) may suggest that they are working in a random fashion, the results of their experiment indicate otherwise. They have become aware of the via media ideas about experiment being developed in the episode. The circuit created by the boys is the clue which indicates that they followed the teacher's guidelines. While depending on their own experience with circuits and their understanding of the problem, they connected a circuit in which "every bulb ... goes back to the power" (p.A106, LL.20-23).

Following this "success", the pupils attempt to explain the use of the copper wire. Their explanation indicates a reliance on their experience with circuits and their limited understanding of uncovered wires, combined with some information acquired in other ways -- a hint at the development of a via media view of explanation.

Episode IV

The impression about science being conveyed in this episode shifts, during the discourse, from the development of a via media view to a formalist conception; the prevailing activity is that of explanation.

It is in this episode that the teacher tries to draw together the results of the pupils' search for a different kind of circuit. The teacher's comparison between the use of covered wires in "our walls" and the simple circuits being explored in the lesson is inadequate to analyze (p.A108, L.25 - p.A109, L.15), especially since she makes no effort to provide a contextual explanation about this "relationship". However, the pupil's comment about short-circuits is noteworthy (p.A108, LL.32-35), since it shows an understanding of the term in the context of the teacher's reference to wires "in our walls". This comment is a clue to the development of a via media view of explanation. Nevertheless, the teacher does not pursue this explanation, preferring to accept the out-of-context comments of a second pupil (p.A109, LL.2-6); this action likely compounded the possible confusion conveyed to the pupils about the use of the copper wire.

The teacher's illustrated explanation of "another" type of circuit appears to be a way of establishing the framework or guideline for subsequent explanations by the pupils (p.A109, LL.13-33). When the teacher solicits the pupils' results from their experiments: "Now. Is there another way that it can be done?" (p.A109, LL.34-36), she again refers to a familiar diagram (p.A110, LL.10-13) and she encourages the pupils to explain their findings (p.A110, LL.19-20). The explanation presented by the teacher draws both from the pupils' familiarity with and understanding of circuits and from her own knowledge. Furthermore, the teacher uses scientific vocabulary in a way which assumes that the pupils understand the context in which the terms are used. These characteristics support the continued development of via media ideas about explanation. That the pupils have become aware of such ideas and are influenced by them is evident by their drawn explanations on page A110, lines 21-22, and again on page A111, lines 15-17. In fact both of these drawings show how the pupils have successfully applied their experience and understanding of circuits to the new problem. However, the teacher's limited acceptance (p.A110, L23, 29-31 and p.A110, LL.18-19) causes the pupils to express some uncertainty: "Yes. Perhaps. Well I don't know" (p.A110, LL.27, 32).

It is at this point in the discourse that the ideas about science are altered. A formalist view takes over for the rest of the episode. The teacher continues to solicit examples (drawings) of different circuits, but she is prepared to accept only one drawn in a particular way (p.A112, LL.27-28).

> T: Okay. Yes, Nadia.
> ... It's good, but
> it's not what I expected. (p.A111, LL.21-23)

Nadia's second effort is also considered to be unacceptable: "No. I'm talking about something else" (p.A111, LL.30-31). Even though the pupils are never apprised of the kind of circuit they are expected to construct, they do fulfil the teacher's request to make "a different kind of circuit" and the pupils' drawings, as mentioned above, are scientifically acceptable representations of a parallel circuit. Notwithstanding the teacher's initial instructions: "I don't care how you connect it up" (P.A104, LL.42-43), she does not consider the pupils' drawings to be adequate. She provides her own version of a parallel circuit (p.A112, LL.27-28) which is the same as that drawn by the pupil on page A111, lines 17-18. The teacher, then, ignores the pupils' own familiarity with and understanding of circuits, which resulted in "correct" explanations, in favour of her own drawn circuit which can be associated, in her view, with parallel lines (p.A113, LL.3-8, 12-23). The impression conveyed here is a formalist view of explanation (and experiment) in that the teacher expects the results of the pupils' inquiry, as well as their account of the activity, to conform to her expectations irrespective of the pupils' understanding. Nothing else will do.

## Episode V

The shift of ideas about science which is noted in the last episode are continued in this brief discourse. The discussion and the teacher's instructions appear to convey both polar views of sensationalism and formalism as well as the development of via media ideas. The teacher instructs the pupils to complete two tasks. One is to answer a question about the intensity of the light when tested with the light meter, and the other is to "sketch a parallel circuit" (p.A114, LL.26-33). The phrasing of her question indicates that sense-data information is expected. There is nothing in the question, nor in the teacher's clarification of the question (LL.35-36), to suggest that the pupils should account for the differences observed, nor are they expected to relate the differences to the varied thickness of the light meter. Rather, the teacher expects a description of the results of the investigation. This appears to convey a sensationalist view of either experiment or observation --both of which would apply.

In requesting a sketch of a parallel circuit, the teacher expects the drawings to conform to her conception of such a circuit. As she circulates in the classroom, she indicates that the pupils are completing the task as expected: "For a change you're drawing your circuits properly ..." (p.A115, LL.4-6). This is confirmed by the drawing completed by all the pupils of one group (p.A115, LL.11-12), but not necessarily by all the pupils of the class (p.A116, LL.3-4). Significantly, the drawing illustrated on page A115 was completed by the same group of four boys whose discourse is analyzed in episode III. This need to confirm the teacher's expectations is characteristic of interactions which convey a formalist view of explanation.

Following this extract, the discourse appears to convey ideas associated with the development of via media ideas about science. The teacher's question about using a covered wire in a parallel circuit (p.A115, LL.12-15) seems to draw on the pupils' experiences with both insulated and non-insulated wires. Significantly, it is the pupils' responses which indicate that their understanding and experience with circuits, as well as information acquired from other sources, are used to explain, in a limited way, how to treat the covered wire for use in a parallel circuit or "in our walls" (p.A115, LL.18-31). The characteristics found in this last part of the episode appear to demonstrate a return to the development of via media ideas about explanation.

The consequences of such alterations in pupils' "meta-learning" (Schwab, 1962) are left for another study to explore; however, the evidence in the last two episodes indicates that contradictory views of science are being conveyed. These contradictions could leave pupils with a confused impression about scientific inquiry.

It would be interesting to find out from the teacher what importance she assigns to the pupils' own experiences and understandings about their experimental inquiry.

## Contextual Support

The interview with the teacher provides contextual evidence that is useful in understanding the shift of ideas about scientific inquiry which is identified in the discourse. The reader is advised to peruse the transcribed interview, found in Appendix B (p.A159 - p.A165), in order to recognize the teacher's views as they are referred to in the interview.

The teacher considers the science programme, from which the lesson is taken, to be inadequate in terms of science information or theory (p.A160, LL.7-13). This leaves pupils with missing links to science understanding which the teacher feels are important for the pupils, especially at the elementary level (p.A160, L.42 and p.A161, LL.1-10). Nevertheless, the teacher does try to follow the experimental thrust of the programme which allows the pupils to "find for themselves what ... they should do" (p.A161, L.41). This might account for the evidence of a sensationalist view of science which is conveyed in the first episode of the lesson. However, the teacher's concern with the need to provide science background in order to help the pupils understand their own experiences (p.A160, LL.18-24, 26-28, and 35-37) is a sufficiently strong view since it is revealed in each episode of the lesson and is identified in the analysis as the development of a via media view of science.

This view is identified in the lesson by the way the teacher and pupils refer to scientific terms, with the pupils apparently understanding the context in which the terms are used. The analysis is supported by the teacher when she indicates that during previous lessons she had provided pupils with explanations of these terms and usually such explanations were given following the pupils' experimental activity (p.A162, L.37 - p.A163, L.8, 21-27). This is one way, then, in which the teacher provides the pupils with the "missing links" she feels they need. Even though the teacher feels that the pupils' own experiences do contribute to their understanding, it is a shallow understanding and she provides science background information or the opportunity for the pupils to carry out "research" whenever it is important to do so (p.A164, LL.6-11).

Significantly, the lesson analysis reveals that the teacher's view of the importance of science information may convey a formalist view of science as it does in episode IV. Here the teacher insists on a particular drawing of a parallel circuit and she provides the pupils with a "rule" for such a circuit, even though some of the pupils presented a perfectly acceptable diagram. When this example was brought up during the interview, the teacher agreed that provision of such rules is a good idea since it helps the pupils complete their task satisfactorily (p.A162, LL.12-25). Considering the teacher's general comments about the importance of combining science information with the pupils' own experiences, the evidence of a formalist view is unexpected. The rule given may be the teacher's way of assuring that all the pupils understand how a parallel circuit is constructed. Nevertheless, the evidence in the lesson is strong indication that a formalist view is being conveyed. (Unfortunately, the investigator did not pursue this point during the interview.)

The lesson revealed two other very brief instances in which a formalist view appeared to be conveyed. These are found in episode II of the lesson (p.A103) and in episode IV (p.A112). Rather than a formalist view, the teacher indicated that she was hoping the pupils would try to "give some reasons why" an "experiment doesn't work" (p.A161, LL.17-28). The teacher attributes the pupils' lack of interest in explaining such events to the programme, with its emphasis on having the pupils find things out for themselves by "playing" with the materials (p.A161, L.38 - p.A162, L.4). The teacher's comment, then, contradicts the view of science interpreted in the analysis, but more significantly, these comments indicate the usefulness of an interview in finding out the context in which the teacher's statements are made during the lesson.

The interview with the teacher supports the major analysis of the lesson discourse and reveals that, although the teacher is expected to implement the programme in one way, she sees the need to provide more science background and theory in order to help the pupils make sense out of their experimental activity. This becomes evident in the lesson as the development of a via media view of science conveyed by the teacher and evident in the pupils' comments and in their activity. The shift in the views of science revealed in the lesson may be a result of the teacher's effort to combine the two views of science, her own view and that of the programme to which she is committed.

## Identification of Clues

Analysis of this grade six science lesson reveals the clarity of the clues found in three categories of the analytical scheme. This means that the characterizations which comprise those categories distinguish among three different views of science which are being conveyed in the discourse. These views are: a sensationalist view provided through both experiment and explanation; and a formalist view conveyed by explanation. Analysis of the lesson further reveals the need to extend and revise some clues found in the category which identifies the development of a via media view of explanation.

Significantly, in terms of the purpose of this study, the analysis exposes new clues not previously identified in any of the lessons analyzed. These clues characterize the development of a via media view of experiment and, to a lesser extent, a formalist view of science conveyed through experimental inquiry.

Sensationalist ideas about science. In applying the analytical scheme to the lesson, clues are confirmed in two categories already presented in the scheme. The characteristics of these categories clearly identify the sensationalist ideas being conveyed in the discourse through the activities of experiment and explanation. Although the pupils are not directly involved in experimental inquiry, the evidence in episode I reveals that, in response to the teacher's questions, the pupils provide sensory information about their prior experiments with the light meter and they talk about their investigations and their results in simple, non-scientific language. In the same episode, the teacher's questions require an explanation about light intensity while the pupils' explanations are descriptions of their own concrete experiences. The lesson analysis, found in Appendix A (p.A92 - p.A116), identifies these two categories with the same codes used in the analytical scheme of Figure 11.

Formalist ideas about science. Analysis of the lesson reveals that formalist ideas about explanation are identified in episode IV and in episode V. The clues which characterize this view of science are clearly evident when the teacher insists on a particular interpretation of a parallel circuit -- a drawing which confirms her own view of how such a circuit should be explained, irrespective of the pupils' own understanding. The teacher further approves of the pupils' final, drawn interpretations which are limited to the rule she had given the pupils. These clues are identified in the lesson analysis in Appendix A, beginning on page A92, with the same code (F-c) as categorized in Figure 12.

Characteristics consistent with a formalist view about experiment appear to be manifest in the discourse of one of the groups of pupils and to a lesser extent by the teacher. The pupils appear to have the impression that their experimental results must confirm the teacher's expectations; to assure that they do, the pupils alter their own findings. The teacher appears to sustain this view since she does not ask the pupils to present all of their results.

This is the only new characteristic which is clearly identified in the discourse. Another new clue is only hinted at in the lesson (p.A103 and p.A112) but it implies that an experiment is successful if the results confirm what is expected and known. Both of these new clues are identified in the lesson analysis in Appendix A (p.A92 - p.A116). The first clue is coded F-b, and the second is coded as a forerunner to such formalist ideas, or p-F-b.

Via media ideas about science. Analysis of the lesson reveals that via media ideas being communicated still appear to be in the developmental stage. That is, there is inadequate evidence in this lesson discourse (or in the previous lessons analyzed) to claim that Hanson's "realistic synthesis" of polar views is clearly identified. As stated previously, it is unrealistic to consider elementary pupils as having acquired the network of science constructs necessary to conceptualize a science activity in the Hansonian sense. In this lesson, such a conceptualization would include a knowledge of and experience with voltage, energy, and all the scientific concepts associated with electrical circuitry. Even though the discourse indicates that via media ideas are not fully formulated, forerunners to such ideas are evident both as revisions to existing clues and as a set of new clues.

Clues which characterize the development of a via media view of explanation are revealed in four out of five episodes analyzed. During the lesson, both the teacher and the pupils use some scientific vocabulary in trying to explain the lesson activity. Not only do the pupils appear to understand the meaning of the terms, but they also understand the context in which the particular terms are used. This latter characteristic is an extension of that already found in the scheme. The discourse further reveals that the teacher's comments relate the science information she wishes the pupils to consider with the pupils' experiences and understandings about circuits. Additionally, the pupils try to make sense out of their new problem, but not by referring to science information acquired in the lesson as characterized by the clue in the scheme. Rather the pupils in this lesson appear to rely on their own experience and understanding of similar circuits. The existing clue, then, for characterizing the pupils' explanations, is inadequate for clearly distinguishing between (possible) different modes of explanation. Consequently, this clue is replaced by new characteristics which take into account new problems, science information pupils may acquire in various ways, and the pupils' own experiences. (These new clues are found in the revised analytical scheme.)

In sum, clues which reveal the development of a via media view of explanation are identified in the lesson analysis in Appendix A, starting at page A92, with the same code, p-M-c, as initially assigned to this category.

The discourse in episode II and in episode III manifests significant characteristics of the development of via media ideas about experiment. The teacher provides the pupils with a framework or the parameters into which their experiments are set. It is this which helps the pupils avoid haphazard inquiry. Within this framework, the teacher may direct the pupils to relevant aspects of their investigation but they are not told what results to expect. Both the teacher and pupils talk about the experimental inquiry by referring to the pupils' prior activity with circuits and their understanding of the context in which the investigation is set. Additionally, as the pupils and the teacher talk about the inquiry, they use scientific vocabulary in a way which reveals the pupils' understanding of the terms as well as the context in which they are used.

These forerunners mark the difference between ideas conveyed at the level of school pupils and the kind of inquiry carried out by Hanson's scientists. The latter are conceptually "able" to recognize an experimental problem, design the inquiry, and identify the relevant results. Elementary school pupils are unable to do this. Notwithstanding the shift of ideas revealed in the discourse, the teacher does establish a guide or framwork so that certain aspects of the pupils' work becomes meaningful. The teacher, then, appears to be bringing the pupils closer to the realization that there is another way in which experimental inquiry can progress. This idea is noted in the interview with the teacher.

These new characteristics of forerunners to a via media idea about experimental inquiry are included in the revised analytical scheme as a new category with the code p-M-b. The prefix "p" indicates that this view of science is being developed in the science lesson. These characteristics are identified in the lesson analysis in Appendix A beginning on page A92.

Application of the seven-category analytical scheme to this science lesson revealed the clarity of some of the clues, the need to modify other existing clues, and new clues not previously exposed in lesson analyses. This application, however, is not meant to provide a definitive set of categories. Rather, analysis of "more" science lessons could expose new activities (such as measurement or use of models) and these would become new categories for the scheme. Moreover, as noted in the lessons analyzed, not all categories are found in each lesson. The scheme, then, is only a model the elements of which may be identified in some lessons and not in others. Consequently, the changes noted above are now incorporated into a revised nine-category analytical scheme.

## The Revised Analytical Scheme

### Sensationalist Ideas About Science

Since no new characteristics have been found to extend or alter the clues to the identification of a sensationalist view of science, the three categories of the analytical scheme found in Figure 11 are maintained. However, some of these clues have been rephrased. These revisions serve to consolidate similar characteristics within a category (as in S-a) and to assure consistency across these categories of the scheme. Thus, three categories which identify that sensationalist ideas about science are being conveyed in the discourse of a science lesson are presented in the revised analytical scheme in Figure 14.

### Formalist Ideas About Science

Analysis of the lesson revealed no new clues for the identification of formalist ideas about observation, and the characteristics which identify formalist ideas about explanation are the same as those in Figure 12. So these two categories are maintained for the revised analytical scheme, with a rephrasing of some of the clues in order to enhance the clarity of the characteristics. The lesson does reveal two new clues for the identification of formalist ideas about experiment, clues not previously derived from lesson analysis. These are now included in the revised scheme as a new clue and as a revision of one of the existing clues, thus replacing two clues previously extrapolated from the other categories representing a formalist view of science. The revised analytical scheme, with three categories for identifying that formalist ideas about science are being conveyed in the discourse of a lesson, is presented in Figure 15.

## Sensationalist Ideas About Science

Elementary science lesson discourse conveys sensationalist ideas about science, if one or more of the following clues are revealed:

| S-a | S-b | S-c |
|---|---|---|
| Ideas About Observation | Ideas About Experiment | Ideas About Explanation |
| T solicits, accepts as much sense-data information as possible without telling Ps what to look at or what to look for. | T solicits, Ps freely gather as much sensory data as possible from various tests. | T's questions may use "why", "explain", or "how do you know" in same context as describe. Requires information derived from Ps' own experiences. |
| Ps are preoccupied with random observations. They perceive what is concrete and obvious through the use of their senses. | Ps carry out experiments in a random manner without T direction as to procedure or results to expect. | Ps answer or explain with sense-data descriptions of what is (or was) concrete and has been experienced. |
| T does not provide scientific information about material being observed. T expects that observations may generate an understanding about the material being examined. | T does not provide scientific information about problem being investigated. T expects that investigation and results may generate new understandings. | T does not provide scientific information in explaining events experienced. |
| T and Ps talk about observations using descriptive non-scientific language. | T and Ps talk about investigations and results using descriptive, non-scientific language. | T and Ps explain events using descriptive, non-scientific language. |

Figure 14. Revised Analytical Scheme. Three categories for the identification of sensationalist ideas about science.

## Formalist Ideas About Science

Elementary science lesson discourse conveys formalist ideas about science,
if one or more of the following clues are revealed:

| F-a Ideas About Observation | F-b Ideas About Experiment | F-c Ideas About Explanation |
|---|---|---|
| T directs Ps so that certain information is perceived which fits the T's expectations and knowledge. | T directs Ps' experiments so that they are carried out in a particular way, according to the T's understanding of the problem. | T directs questions or requests explanations so that acceptable information is provided which T expects and knows. |
| Ps' observations are limited to and confirm expectations, irrespective of their own perceptions and experiences. | Experiments are successful if data gathered by Ps confirm T's expectations and preconceptions. | Ps' explanations limited to science information (rules) given. Not related to their own experiences. Confirm T's expectations. |
| Ps' observations may be altered to confirm what is known and expected. | Ps may talk about changing results or repeating an experiment if results contradict expectations. | T's explanations include science information (rules, definitions) derived from T's knowledge, irrespective of Ps' understanding and experience. |
| T and Ps may use, scientific vocabulary when referring to observations with no evidence of a link between the terms used and Ps' perceptions. | T and Ps may use scientific vocabulary when referring to procedures or results. Ps may not understand meaning of terms in context of investigation. | T and Ps may use, scientific vocabulary with no evidence of a link between terms used and Ps' understanding of terms in context of explanation. |

Figure 15. Revised Analytical Scheme. Three categories for the identification of formalist ideas about science.

## Via Media Ideas About Science

Analysis revealed the need to revise clues for identifying that a via media view of explanation is developing in the discourse. The revisions include an extension of one clue (referring to the use of vocabulary) and the establishment of two clues to replace the existing characteristics for the identification of pupils' mode of explanation. These new clues are presented in the revised analytical scheme in Figure 16 and characterize the development of via media ideas about explanation.

Analysis of the discourse further exposed new clues, not previously found in any of the lessons analyzed, for the characterization of via media ideas about experiment which are being developed in the lesson. These now become an eighth category of the revised analytical scheme and are found in Figure 16 with the code p-M-b.

None of the lessons analyzed revealed clues to the development of via media ideas about observation. However, in order to assure the comprehensiveness of the analytical scheme for analyzing future lessons, it is now considered necessary to include a category for the identification of such ideas. This category would also maintain the integrity of Hanson's conceptions about scientific inquiry and it would provide a completeness to the scheme. This new category is derived by suggesting the kind of characteristics which would be evident if such a view were being conveyed in a lesson. The suggested characteristics are extrapolated from those clues which comprise the categories for identifying the development of a via media view of experimental inquiry and explanation. Since both of these categories are derived from analysis of lesson discourse, this investigator believes there is now sufficient evidence to use these clues for the derivation of the new category.

Consequently, clues to the new, ninth category of the revised analytical scheme are included in Figure 16 with the code p-M-a. The prefix "p" continues to be retained as an indication that such ideas about science are being developed in a lesson. The clues are presented in "script" type to note that none of the characteristics have been derived from analysis of discourse.

Thus a nine-category analytical scheme has been developed. The question now is whether the clues of the scheme can be recognized in the dialogue of a science lesson by persons who were not party to their development. The chapter concludes with a discussion of an assessment of the clarity of the clues carried out by two independent judges.

## Via Media Ideas About Science

Elementary science lesson discourse is developing via media ideas about science, if one or more of the following clues are revealed as forerunners:

| p-M-a Ideas About Observation | p-M-b Ideas About Experiment | p-M-c Ideas About Explanation |
|---|---|---|
| *T provides "set" or framework for Ps' observations so that certain features are recognized and others ignored.* | T provides "set" or framework for Ps' experiment so that aimless activity is prevented. | T's explanations relate science information with Ps' own understanding and experiences. |
| *Ps talk about certain observations as more relevant than others because of their understanding and experience.* | Ps and T talk about experiment by referring to Ps' prior experience and understanding of context in which investigation is carried out. | Ps' explanations make connections between science information acquired from T or other sources and their own experiences. |
| *T and Ps link perceptions to what is known or understood about material and to Ps' own experience with same or similar material.* | T does not indicate what results to expect, but Ps directed to relevant aspects of investigation. | Ps make sense out of new problem by drawing on prior experience with and understanding of similar material or events. |
| *T and Ps use complex, scientific vocabulary when talking about observations. Ps understand meaning of terms and context in which used.* | T and Ps use complex, scientific vocabulary when talking about results or experiments. Ps understand meaning of terms and context in which used. | T and Ps use complex, scientific vocabulary to explain events.<br>Ps understand context in which terms used. |

Figure 16. Revised Analytical Scheme. Three categories of forerunners to the identification of via media ideas about science.

## Assessment of Clarity

In order to assess the clarity of the clues which comprise the revised analytical scheme, two independent judges were invited to apply the scheme to the same grade six science lesson analyzed by this investigator. The resulting analysis was then compared to that of the investigator using a methodology borrowed from Orpwood (1981). Even though the judges did not have the advantage of the contextual knowledge held by the investigator, nor training in the use of the scheme, a significant correspondence was found among the three analyses. This indicated that the clues can be identified, in the lesson analyzed, by persons other than the developer.

This investigator had the advantage of being an observer of each science lesson and consequently knew "what was going on" in the classrooms. This knowledge was inevitiably reflected upon during the lesson analysis. The investigator could also listen to the recorded lesson as often as necessary in order to further refine the analysis and improve the clarity of the clues. Additionally, the interviews conducted with the teachers resolved problems of context which were encountered. This extensive personal knowledge influenced and facilitated derivation of the clues and later, application of the scheme. The judges, on the other hand, had no such experience or knowledge of the context of the lesson to be analyzed.

Both professional people in science education, the judges were not only unaware of each other, but live thousands of miles apart. They were given a review of the study and instructions for application of the scheme. Copies of these documents are found in Appendix C, page A167 to page A172. They were also provided with a copy of the nine-category analytical scheme and an unanalyzed copy of the grade six science lesson, Batteries and Bulbs, which they were asked to analyze and code as completely as possible. (The investigator's analysis of this lesson has been referred to previously and is found in Appendix A, p.A92 - p.A116.) A fully analyzed grade four science lesson was also provided as an example of how the clues were identified in the discourse by the investigator. A copy of this lesson is found in Appendix A (p.A117 - p.A139)[1]. No other information was given and there was no further communication with the judges regarding the analysis or the scheme. The judges were, however, invited to comment in writing about any difficulties they encountered in application of the scheme.

Orpwood (1981) diagrammed the results of the analysis of an issue in curriculum deliberation by comparing his analysis with that of a colleague-judge. The common analyses in the use of the major categories of his analytical scheme determined the degree of correspondence between the two judgements. For the present study it was more difficult to compare the three sets of judgements since the two judges and this investigator often analyzed different portions of the dialogue within an episode or even within an extract. To overcome this difficulty, the comparison was made only on those extracts (or approximately the same extracts) which all three persons analyzed. For example, the investigator may have analyzed 10 extracts of discourse which revealed a formalist view of science. However, if only six of the extracts analyzed by the judges coincided with those of the investigator, then only the judgements about those six were compared. In this way 29 coinciding extracts were found in the lesson, a number which the investigator deemed to constitute a sample for comparison. With the investigator's identification of clues used as the basis for the comparison, Table 1 reveals the extent of correspondence between the investigator's analysis and each of the judges. An explanation of one group of figures in the Table is in order. Out of the 29 extracts analyzed by the three persons, six of these were judged by the investigator as conveying a sensationalist view of science. Of those (same) six extracts, judge A identified four as conveying a sensationalist view and judge B identified four as conveying the same view of science. In this way correspondence is shown for the other views of science as well as for both the views of science and the same science activities.

Table 1

Correspondence Between Investigator and Judges in Identification of Views of Science*

| Investigator's Analysis | | Analysis Corresponding to Investigator | | | |
|---|---|---|---|---|---|
| Views of Science | | Views of Science | | Views and Activities | |
| | | Judge A | Judge B | Judge A | Judge B |
| Sensationalist | 6 | 4 | 4 | 4 | 2 |
| Formalist | 8 | 7 | 5 | 6 | 3 |
| Via Media Developing | 15 | 12 | 9 | 8 | 5 |

* Based on 29 extracts analyzed by three persons.

Furthermore, it was found that the analyses carried out by the two judges also showed a substantial correspondence. The comparison is based on 23 extracts from the discourse which were analyzed by both judges. Of these, 18 showed a corresponding judgement for the views of science and 15 were judged to show both the same views of science and the same science activities. This information is presented in Table 2. Even though the judges had no contact with one another, they were each able to apply the scheme to the same lesson and, frequently, to recognize the same views of science being conveyed through the same activities.

Table 2

Correspondence Between Judges' Analyses*

| | Corresponding Views of Science | Corresponding Views and Activities |
|---|---|---|
| Sensationalist | 3 | 2 |
| Formalist | 6 | 4 |
| Via Media Developing | 9 | 9 |

* Based on 23 extracts analyzed by both judges.

It is the investigator's judgement that the correspondence displayed in Tables 1 and 2 constitutes sufficient qualitative evidence to support a claim that the clues of the scheme are clear enough, by and large, to be recognized in the discourse of a science lesson by independent judges. However, notwithstanding this evidence, problems of interpreting what activity was going on in the classroom were encountered by one of the judges. This judge felt that the characteristics separating the activities were not sufficiently distinct. The same kind of difficulty was dealt with by the investigator during the analysis of the four lessons. Such problems might be alleviated by further refinement of the clues so that the parameters of each activity are more clearly defined. Nevertheless, it would be difficult to isolate the activities since they are interrelated in elementary school lessons, as they are for scientists. Another way of reducing problems in applying the scheme would be to train practitioners to focus on certain characteristics in the dialogue. Although one judge encountered some difficulties, the other judge found "the categories easy to use."

Further assessment of the analytical scheme and refinement of the categories is left to another study. However, the assessment carried out, at this stage in the development of the scheme, indicates that the clues of the scheme can be recognized in the discourse of a science lesson and do reveal the views of science being conveyed.

## Summary

This chapter concludes the development and the assessment of a nine-category analytical scheme. Initially, the analytical scheme was composed of seven categories developed from the initial clue structure. This scheme was applied to a grade six science lesson to reveal the clarity of some of the existing clues and the need to revise others. Furthermore, analysis exposed new clues not previously identified in any of the science lessons analyzed.

New clues for the identification of formalist ideas about experiment were incorporated into the scheme to replace two existing clues which had been extrapolated from related characteristics. A set of clues for the identification of the development of a via media view of experiment were also revealed and these were incorporated into the scheme to become an eighth category. The characteristics of the ninth category of the scheme, the development of via media ideas about observation, were extrapolated from the related clues which identify the development of via media ideas about experiment and explanation. In this way the analytical scheme was revised to include nine categories.

In order to assess the clarity of the clues, the newly developed scheme was applied to a grade six science lesson by two independent judges. A discussion of the judges' analyses revealed a significant correspondence between their analyses and that of this investigator. This indicated that the clues of the analytical scheme are clear enough to be identified in the discourse of a science lesson by persons who were not involved in the development of the scheme nor trained in its application to lesson dialogue. The assessment further revealed how the different views of science were being conveyed during the lesson.

The final chapter of this dissertation will reflect on the findings of this study and the implications for further research.

Notes

1. The analytical scheme was applied to this lesson by the investigator. The interview with the teacher has not been included in the Appendix (as were the other interviews) since it was not sent to the judges. Examination of the lesson analysis reveals new clues to the development of a via media view of observation, clues which have not previously been found in lesson analyses. Moreover these clues confirm those already presented in the revised analytical scheme.

# CHAPTER VII

# CONCLUSION OF THE STUDY

In this study, the investigator has derived an observation scheme for identifying and characterizing ideas about the nature of science which are being conveyed to elementary school pupils during science lesson interactions. Furthermore, the scheme identifies the manner in which the pupils become aware of these ideas. This final chapter will present a brief review of the major components of the study, followed by a reflection on the results. The chapter concludes with a discussion of the implications of the study for further research and for science education practice.

## A Review of the Study

### The Problem

In the first chapter of this study it was argued that ideas and beliefs about the nature of science held by teachers are being conveyed implicitly to their elementary school pupils through a variety of teaching acts. It was further argued, and justified, that pupils become aware of these ideas just by being exposed to them during regular science lessons. Over a period of time these conceptions could be measured as the various products of science teaching. This investigator, however, chose to study a more immediate aspect of this problem by identifying and conceptualizing the evidence of the ideas to which pupils are exposed, and the manner in which teachers provide for these ideas. This was accomplished by developing a scheme for the observation and analysis of classroom interaction -- both teacher-pupil dialogue and science activities -- as these occur during science lessons.

Viewing the problem in this way is a result of the investigator's professional experiences in teacher education and classroom supervision, which have revealed that elementary school pupils are becoming aware of varied, and confusing, messages about the nature of science. The study argues that in order to discuss teaching behaviour and pupil responses with both preservice and in-service teachers, practitioners with such responsibilities should have immediate evidence of the kind of ideas being conveyed before these are assimilated by pupils or measured as products of science teaching. Without such information, it is not realistic for practitioners to rationalize modifications to science education practice.

A review of related research in Chapter II indicated that there have been numerous investigations of classroom interactions through both product and process studies. Various types of rating scales have been used to measure the outcome of science teaching in the form of achievement in science, attitude toward science, and pupils' understanding of science. Other studies have examined the processes of science teaching by using observation instruments to describe and record the frequency of interactions and classroom events. None of these studies conceptualized the substantive elements of those interactions or events. Nor do these studies identify the provision of conflicting views of science -- all of which ultimately affect the children's developing conceptions of the nature of science.

This study is considered to be a special kind of process research in which philosophical analysis is the basis on which analytical schemes have been developed. Research has demonstrated the power of these tools for identifying and understanding scientific ideas conveyed by secondary school discourse and by secondary school teaching materials. This dissertation, however, differs markedly from previous analytical research. The difference is found in both the manner in which the observation scheme is derived and the purpose for which the scheme has been developed. By a reflexive analysis of classroom interactions and theoretical perspectives, the scheme is developed and used to identify the nature and provision of ideas about science in the elementary school -- the formative years of the children's developing conceptions of the nature of science.

A Theoretical Perspective

The search for a theoretical perspective appropriate to the problem led to philosophical analysis and, in particular, to the work of Norwood Russell Hanson. Hanson characterized views of scientific thought by analyzing the differences between the polar views of sensationalism and formalism, and a balanced view, via media or "middle of the channel". Hanson further organized his characterizations by referring to the varied activities of scientists (such as observation, explanation, verification, theory development). This comprehensiveness provided the needed, and useful, categories for analyzing elementary school science discourse and activity. Selected scientific ideas of Ernest Nagel and Rom Harré were also examined but not found to be appropriate for the context of elementary school science. Nevertheless, the views of these three philosophers are outlined in Chapter III with emphasis given to Hanson's analysis of scientific ideas. Chapter IV examines how Hanson's characterizations are adapted to the discourse and activity of children and to the realities of elementary science teaching, with suggestions of how his views of the nature of science might be manifest in the lesson interactions. The theoretical perspective of the scheme, then, is derived from Hanson's conceptions of scientific thought: sensationalism, formalism, and via media. However, it is limited to those activities which this investigator considers to be the most plausible for initial investigation of science lesson discourse in elementary school: observation, experiment, and explanation.

## Derivation and Application of the Scheme

Analysis of three elementary school science lessons in Chapter V revealed that it is possible to identify Hanson's conceptions of scientific thought and activity in elementary science lessons. True, these conceptions were not evident to the same extent as they might have been when observing and analyzing the discourse and activity of scientists. The philosophical categories required translation from the level of scientific activity to that of school activity; from the thinking of scientists to that of elementary school children and teachers. Thus derivation of the categories of the analytical scheme was accomplished by a reflexive methodology, from Hanson's conceptions to classroom reality, and the results show that it was possible to do this. Moreover, the investigator's presence during the science lessons and the subsequent interviews with the teachers provided a contextual understanding to support this reflexive analysis. A set of initial or preliminary clues were revealed in this way. These clues characterized sensationalist ideas provided by the teacher through the activities of observation, experiment, and explanation. Formalist ideas provided through observation and explanation were also exposed and via media ideas about explanation were found to be developing.

These clues were then summarized as a seven-category analytical scheme in Chapter VI. It was also the task of that chapter to test the clarity of the clues by applying the scheme to a new science lesson. The application was done by the investigator and revealed that the derived clues were indeed recognizable in the lesson interactions. Moreover, new clues, not previously manifest in the science lessons, were also exposed. Additionally, application of the scheme indicated the advisability of modifying some existing clues to improve their clarity. The new clues, and the modified clues were then consolidated into a revised, nine-category analytical scheme.

Another assessment of the clarity of the clues of the analytical scheme was carried out by two independent judges. This was done by application of the revised scheme to the final science lesson analyzed by the investigator. The results of this application and analysis are examined in Chapter VI. Even though the judges did not have the personal knowledge held by the investigator nor training in the use of the scheme, their analysis showed a significant correspondence with that of the investigator. This assessment, then, reveals the capability of the analytical scheme for identifying the views about the nature of science being conveyed during an elementary science lesson and the provision made by the teacher for pupils to become aware of these ideas.

The resulting categories of the scheme and this assessment of the clarity raise other issues which merit further discussion.

## A Reflection on the Results

### Categories of the Scheme

The results of the study indicate that it has been possible to derive an analytical scheme which characterizes the views of science closely approximating those conceptualized by Hanson.

Sensationalist ideas were found to be the most closely related to Hanson's conception of scientific thought and activity. This was anticipated in the discussion in Chapter IV and became clear in the analysis of the first lesson. The same kind of sensationalist ideas are also extensively conveyed in the sample lesson analyzed for the judges (Appendix A, p.A117 - p.A139). The dialogue of the teachers, in both classes, provided the evidence that sensationalist ideas were being communicated to the pupils. Furthermore, the comments of the pupils evinced ample evidence of their awareness or uptake of these ideas.

In analyzing the science lessons, the formalist view of science was found to be a "mere shadow" of the characterizations outlined by Hanson. This too was anticipated in Chapter IV since it was unrealistic to assume that elementary school pupils are able to argue about theoretical preconceptions of which they have no understanding. Thus for the purpose of identifying a formalist view of the nature of science, the source of theoretical knowledge is the teacher rather than the scientific community. Such a transfer of scientific understanding to the teacher creates difficulties in distinguishing between the philosophical characterizations of formalist thought and the more intuitively recognized pedagogical characteristics. However, analysis of the lessons indicated that it was possible to identify the provision of formalist ideas about science in the lesson discourse. The study revealed that via media ideas about science, as conceptualized by Hanson, were not exposed in the discourse of the lessons analyzed. However, such views were found to be developing in three of the four lessons. In fact, the development of this view of science was provided most frequently in the grade six lesson and, significantly, the pupils' comments indicated their uptake of these ideas. As reasoned in Chapter IV and again in Chapter VI, elementary school children have not acquired the scientific understanding of Hanson's scientists. Nor have most teachers. It is conceivable, however, that via media ideas about the nature of science might be more fully identified by other investigators in some other way. Moreover, the science programmes used by the teachers may not have provided for such conceptualization about science and hence these views were not conveyed by the teachers. It is most probable that the scientific understanding inherent in such a view of science is too abstract for the elementary school level. The pupils must develop requisite scientific conceptions over a period of time, counted in years of intellectual development and experience as well as knowledge acquired through schooling.

Perhaps Piaget's theory of intellectual development can play a role in understanding this development of pupils' conceptions. According to Piaget, pupils "arrive" at the level of formal thought through a series of growth stages in which maturity and learning carry the children through increasing complexities of intellectual growth. In science education the same kind of "growth" may be seen. As the children move through the school levels, they acquire increasingly complex ideas about science.

This study provides some evidence of the "growth" of scientific understanding from grade four to grade six. The first and third lessons analyzed (both grade four classes) revealed that polar views of science were being provided by the teachers -- sensationalism in the first lesson and formalism in the third lesson. In the second lesson (grade five), the pupils appeared to have a greater understanding of the problem being discussed. Nevertheless, whether or not the teacher recognized this, a formalist view of the nature of science dominated the discourse of the lesson. Analysis of the fourth lesson (grade six) revealed an increased understanding of scientific inquiry and greater evidence of the development of a via media view of the nature of science.

No claim is made here that analysis of four lessons provides sufficient evidence to state that as pupils progress through the school levels they acquire more complex science concepts or a greater understanding of scientific inquiry. The results of the study suggest that the pupils in these four lessons appeared to become aware of the nature of science through the influence of both sensationalist and formalist ideas which were being conveyed during the lessons. It is conceivable that provision of polar views of science may be more appropriate for the early school levels, considering the experiences and development of the children. These views of science may eventually come together as a more complex, balanced understanding of scientific inquiry and thus demonstrate the influence of a via media view of science. However, it is also possible that the sensationalist and formalist "mix" which pupils experience during their science lessons may result in a confused understanding of the nature of science.

It is beyond the scope of the present study to make definitive comments about which views of science should be communicated, at different age levels, for development of an appropriate understanding of the scientific enterprise. The results of the study demonstrate that it is possible to identify and systematically categorize ideas about the nature of science to which pupils are being exposed during elementary school science lessons, and how the teacher provides for these ideas. The long-term influence on pupils' understanding of science which results from exposure to one kind of idea rather than another, or to a succession of different kinds of ideas, is a tempting question nonetheless.

### Assessment of Clarity

The results of an assessment of the scheme, carried out by two independent judges, were examined in Chapter VI. That discussion mentioned the difficulty encountered by one of the judges in distinguishing between the science activities. The difficulty is a result of the repetition of characteristics between the activities of a particular view of science. It was suggested that perhaps further refinement of the clues might alleviate the problem and/or practitioners might be trained to focus on certain characteristics in the dialogue. A further condition is now added to these suggestions. To facilitate making clear judgements, practitioners should have a contextual understanding of the classroom organization and the science programme in use. This recommendation is based on the experience of the investigator. The relationship between activities became evident in Chapter V and was noted by the investigator as creating difficulty in isolating the characteristics of the activities. The problems were overcome because of the contextual knowledge held by the investigator, gained by being present during the lessons and by interviewing the teachers. Decisions about the activities were the result of both the evidence in the discourse and contextual considerations.

A further methodological problem may arise during any future application of the scheme to science lessons. The point was raised by one of the judges but was not discussed in Chapter VI during the examination of the assessment of the clues. The problem may be found among the clues of the scheme. For example, how would a practitioner-investigator know that the pupils' comments are, or are not, related to their own experiences? And, how would a practitioner-investigator know that there is, or there is not, a link between the pupils' use of scientific terms and their understanding of these terms? The characterization of such clues, by this investigator, was based on a contextual understanding of the lessons and the classroom environment. Then, a user of the scheme should also have such understandings in order to make clear decisions that certain clues are evident in discourse. These recommendations are given even though the analysis of a science lesson carried out by both independent judges, who had no such knowledge, closely corresponded to that of the investigator.

## Implications of the Study

The results of this study permit the investigator to suggest that the analytical scheme has the potential for contributing to further research and to understanding and improving science education practice.

## Potential for Further Research

Assessment of the clarity of the clues of the scheme has been considered. However, only a single independent assessment was carried out. Even though the clues were found to be recognizable in the study, it would be appropriate to pursue this area of research. Further assessment of the scheme might improve and refine the characterizations so that the difficulties which were encountered in distinguishing between the activities may be reduced.

A further extension of this research would be to apply the scheme to other elementary school science lessons. The results would provide evidence of the portability of the scheme. Furthermore, application of the scheme to science lessons in a large number of classes in a school or a school board could reveal information about the views of science being conveyed in each school, and within a school system.

This analytical scheme might be used in association with other scales for the assessment of pupils' achievement in science. Such correlational studies would be valuable for making inferences about the consequences for pupils when exposed to certain views of science.

Analysis of the lessons revealed that conflicting views of science were frequently conveyed during the science lessons. The interview with the teacher also revealed a possible conflict between the teacher's own view of science and the influence of the science consultant or the science programme in use. It is conceivable that the view of science communicated in a lesson (or lessons) may be the result of a particular conception of science formulated in the school (or school board) curriculum, or endorsed and transmitted to the teachers by the science consultant. Since the selection of schools for this study was based solely on accessibility to classrooms with regular science teaching, the views of science exposed were the result of the evidence found in the particular science lesson analyzed. Thus a potential area for further research would be to investigate the influence of the science programme or the science consultant on a teacher's view of science and the way in which that view is provided.

Even though the investigator selected three science activities as the ones which would most likely be evident during the lessons, it is possible that analysis of further lessons would reveal other activities, and thus new clues, for the provision of ideas about the nature of science. In fact the relationship found between the characteristics of the activities could facilitate the derivation of new categories for the analytical scheme, thus expanding its comprehensiveness.

### Contribution to Science Education Practice

Use of the analytical scheme in clinical supervision can contribute significantly to analysis and modification of the teaching behavior of practicing and preservice teachers. Teaching behaviour is often a result of quick action and intuitive judgements with little time taken for a deliberation of classroom activity. The scheme could provide clear evidence about how conflicting meta-learnings about science are being communicated to the pupils. Such evidence would enable practitioners to openly discuss the potential consequences of such confusing messages on the pupils' understanding of science. Moreover, the relationship found between the categories of the scheme permits predictions to be made about the kind of messages which can be conveyed, and thus facilitates the planning of changes to individual teaching practice.

Unfortunately application of the analytical scheme in classroom supervision presents difficulties in terms of the length of time needed for transcribing and analyzing lesson discourse. Nevertheless, the potential power of the tool for understanding and discussing both teacher and pupil performance during lessons indicates that the needed "time" could be judiciously allocated. Moreover, as skill in the application of the scheme increases, transcription and analysis of "patterns of behaviour" may be carried out rather than complete lesson analysis.

Teacher education programmes are considered to have a significant influence on the manner in which teachers organize their science lessons. Systematic analysis of science course interactions during such programmes would present teacher educators and supervisors with useful and important information about their own views of the nature of science and how these are provided to their student teachers. A longitudinal study may also be carried out to investigate the views of science conveyed by the pre-service teachers during their field experience and then, subsequently, in their own classrooms. This would provide important information about the science education programme.

It has been suggested that views of science which teachers convey during science lessons may be influenced not only by the teachers' science background and training but also by the school science programmes or the science consultants. In order for decisions to be made about the choice of a science programme, it would be valuable to determine the nature of the ideas about science which are conveyed by the teacher's mannuals or elementary school science textbooks. Application of the scheme to such elementary school curricular materials would identify not only the view of science stressed by the programme but also the nature of the activities by which the pupils would become aware of these ideas. Moreover, application of the scheme during implementation of new science programmes would enable the teachers to identify whether or not curricular intentions are being met and the most effective manner in which to do so.

One area of science education practice for which this scheme may be very useful is in application to the discourse of science lessons in special education classes, with both slow-learning pupils and gifted children. Understanding how to convey ideas about science to these pupils could have a significant influence in developing science curricula and/or in modifying teaching behaviour so that pupils become aware of desired ideas about the nature of the scientific enterprise.

## Summary

This final chapter has reviewed the problem of the study and the manner in which the problem was addressed. The analytical scheme, which was developed, is based in philosophy of science and analysis of elementary school science lessons. As an observation tool, the scheme enables practitioners to identify and to characterize three views of the nature of science which are provided by teachers during ordinary science lessons: sensationalism, formalism, and via media. The scheme further indicates that the pupils become aware of these ideas through the activities of observation, experiment, and explanation. Following derivation and refinement of the clues of the scheme, the clarity of these clues was assessed by two independent judges.

In reflecting on the results of the study, the investigator concludes that derivation of the scheme for the analysis of elementary school science lessons has important implications for further research and, for improving and understanding science education practice.

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# APPENDIX A

## Transcribed and Analyzed Science Lessons

Notes on use of dash and period in transcript:

| | |
|---|---|
| ---- | dialogue not heard clearly enough to transcribe |
| -- | continuity of statement interrupted |
| ... | interruption by another speaker |

## SCIENCE LESSON - 04

### Mystery Powders

(Pupils sitting and talking together in groups waiting for Teacher to light their alcohol burners.)

(The lesson begins.)

Episode I: S-a; (S-b)

(L.1 - p.A7, L.5)

Teacher: ---- Now pour some powder in your dish. Be sure it's powder I. The reason why two of you brought your powders was to make sure that you have enough, eh? You need to put a little bit more than when we did the water test and the iodine.

Pupil: And the vinegar.

LL.9-19: S-b

T provides no instructions as to amount of powder to use or the results to expect.

T: This you can judge for yourself as you go on -- if you have enough, eh?

(When burners are lit Ps put small aluminium dish containing powder sample, on the tripod, over flame of burner. One P in each group stirs the powder. All Ps chatter noisily about their work. T circulates, adjusting the burners.)

Ps carry out test without direction until p.A3, L.11 when T calls for observations.

T: (To one group) Now put your dish on ----. Remove your cover (of the burner).

T provides vague reference to care in test procedure.

P: Nothing's happening.

T: Of course, you're putting out the fire.

P: Miss, our fire's out.

T: I can smell things there, can you?

Ps: Yes.

T: Daphne?

1 P: Nothing in ours.

T: Nothing's happening? Give
a chance to your ----.

P: It turned brown.

5 T: Ah, that's something you
noticed.

(Ps talking very noisily. Not
possible to identify all the
dialogue.)

10 P: It's black.

P: It smells like burnt toast.

Ps: Yeah.

T: OK. It smells like burnt
toast. Don't let it burn com-
15 pletely through, 'cause your
aluminium plate will ----.

(Microphone taken to the side
of Group 2.)

P: It smells like burnt toast.

20 P: Now it's hard. It's so hard!
(P stirs powder in aluminium dish.)

P: It's not black, it's brown.

P: Stir the sides.

P: The burner's not working.

25 P: It's hard.

T: Estelle, what's the first
thing that you notice?

P: It turns black, fast.

T: OK. Give the others a
30 chance to stir. Watch your
plate there and I'll try to
start your fire. (T lights
burner and Ps resume stirring.)

P: It's sticking.

LL.5-14: S-a

Ps talk about observations using descriptions based on their senses.

LL.13-16: S-a

T's comment refers to sensory observation.

LL.19-23: S-a

Ps talk about powder using simple non-scientific vocabulary.

LL.26-28: S-a

T asks P what was observed. P provides a description of the test result.

P: Yeah.

P: I can't get it off.

P: Do you know why it sticks?

P: It's burnt toast, sort of.

P: It's hard.

P: Miss, it turns hard.

P: It smells like burnt toast.

P: It smells like popcorn.

LL.1-8: S-a

Ps make random observations of changes in powder. Talk about powder using simple descriptions of what is perceived.

T: OK. Now children all our fires are out. Just leave your dish there and let's write down what we have discovered with -- what we have observed with our powder I. First of all, we used what?

LL.11-14: S-b and S-a

T calls for the results of the test, implying that whatever was discovered is important. At the same time she refers to the results as observations.

P: Flour?

T: Flour. Powder I was flour. (T writes on chalkboard.)

Heat Test

Flour:

In group number 3, there, what was your first observation? Bertrand?

Bertrand: It turned brown.

LL.21-26: S-a

T solicits and accepts sensory descriptions as the observations.

T: It turned brown. (T writes on the board beside the word flour.)

Flour: The powder turned brown.

(T interrupts noisy pupils.) Hold on boys. Let's listen here to Sylvain.

Sylvain: If we mix it, it's hard.

LL.31-34: S-a

T accepts random sensory observations.

T: It's hard and what else did you notice there? (Ps all talking at once.) One at a time please!

P: It smells like a burnt toast.

T: So what does burnt toast smell (like)?

P: Burnt.

P: It smells fire.

T: It smells fire! Let's go back to Sylvain here, OK? So when you touched it what did you notice? (Ps chattering loudly.) Sh! We're not listening over there!

Sylvain: It's hard to touch.

T: OK. And --

Sylvain: And it comes soft again.

T: By doing what? What are you doing there?

P: ----

T: Can you find a better word for that?

Sylvain: Crunching it.

T: You're not crunching it. What are you doing to it?

P: Rubbing.

T: Right ----. What is yours like Ann? What do you feel there, when you -- ?

Ann: Like sand.

T: Well, what does sand feel like?

Susie: Soft?

T: It's soft eh? Well, let Susie have a chance there. Susie thinks it's soft. Who are those that find that their mixture, after being burned, turned out soft? Is there only Susie that

LL.2-6: S-a

T requests and accepts observations based on senses.

LL.7-13: S-a

T encourages Ps to use their senses in making observations.

LL.14-23: S-a

T prefers descriptive terms for observations.

LL.24-31: S-a

T insists on P "feeling" the powder prior to describing it.

Sensory perception is stressed.

found that out?

Ps: No.

T: I think you all have to put your little fingers in there. Feel it.

Ps: Oh! Feel it!

T: Oh! It's not soft.

T: Ah! Scratchy and -- ?

P: Miss, some of it is soft.

T: OK. Let's go on with your observations. What is the colour?

P: Pepper.

T: Well, what is the colour of pepper eh? When you tell me it's the colour of sand, or salt and pepper, this is an establishment (sic) that has been done. Somebody has decided this would be called pepper, this would be salt. (Ps: Sh! Sh!) We cannot say it has the colour of sand. We all agree to that?

P: It has black pieces.

T: Right! What else?

P: Some of it is soft and some hard.

T: Sylvain is trying to explain that some parts are soft and some other parts are not. But what do you discover when you feel it? Press on it and see what happens.

P: It's lumpy.

T: It's lumpy, yes. Lumpy and rough. And what are you doing with your finger now?

Ps: Rubbing it.

LL.3-9: S-a

T implies that sensory observations may reveal something important.

She accepts various sensory observations made randomly.

LL.10-13: S-a

T encourages Ps to talk about observations using visual and tactile descriptions.

LL.28-36: S-c

T uses term "explain" in the same context as describe. She refers to discovering what is felt and she accepts Ps' sensory descriptions of what is experienced.

T: You're rubbing it. What happens next?

P: It's rough.

T: It's rough.

P: Dry.

T: Rubbing your powder, there, with your finger. Press down, or even take a wee bit between your two fingers and see what happens.

Ps: Rough.

P: No.

Ps: Dry.

T: And, were you able to get some? All of you? Well Jason, go on. We feel ---- OK.

P: It's scratchy.

T: It's scratchy.

P: Lumpy. It's lumpy.

LL.6-19: S-a

T implies that tactile perception will reveal important characteristics.

Ps describe powders.

T: Now we discovered -- . How many agree that, at the beginning after mixing it, our powder turned out to be lumpy? (A large number of Ps raise their hands.) OK. We can go on. What did you also discover after, Sylvain?

Sylvain: If you keep on rubbing it, it becomes soft.

T: Right, if you rub it, the lump will -- .

Sylvain: Disappear.

LL.20-33: S-b

T calls for the results of mixing powders, implying investigation may reveal information worth knowing. She requests discovered information and accepts Ps' descriptive result of handling powder.
T provides no information about powder or results Ps should expect.

T: Dissolve, vanish, disappear. (T writes on board under first description about flour.)

: Rubbing the powder

LL.33-p.A7, L.2: S-a

T records certain concrete observations. Implies that some results, from among the with fingers, the lump disappeared.

OK. Now each one of you will take her plate, put it aside.

P: The plate's burnt.

T: That's why we have to change. We go to powder #2. Powder #2. We'll go to -- . (T hands out new aluminium dishes.)

P: Clockwise.

T: Clockwise? Fine.

(Ps noisily chattering and getting ready for next activity. T lights alcohol burner for each group.)

(Microphone set at fringe of Group 3.)

Ps: Put it on.

P: He's doing it this time. (P stirs powder.)

P: Nothing's happening. It's still white.

P: It's gonna come, not black, but like yellow.

P: It's gonna come like the ---- powder, like before, maybe yellow.

P: Maybe not, because it's ----.

P: Yeah.

P: I wonder what's gonna happen.

P: It stinks!

P: I don't know. It doesn't smell.

P: I don't smell anything.

P: (In background, screaming) Oh, oh, Miss, oh, look!

observations made, are important and worth noting.

Episode II: S-a

(L.7 - p.A15, L.30)

LL.8-19

Classroom Management

LL.22-32: S-a

Ps expect to see colour change in sugar as a result of heating. Random collection of sensory observations.

1 P: Miss, it's like syrupy.

T: Don't let it burn, though, watch your fingers.

(Heard from Group 3 in foreground)

5 P: Yeah.

P: I bet it's gonna start melting.

P: Yeah.

P: Yeah, maybe.

P: Yeah, because when ---- .

10 P: The stuff around the crystals ---- .

P: Yeah, there it's melting.

P: I told you.

P: I bet the crystals won't melt.

15 P: Yeah, they're gonna melt.

P: Yeah.

T: (To all groups) This group's made very good observations here. If you have had a chance to have
20 already seen what's going on. Give your group a chance. Don't --.

P: Yeah.

Ps: Ah! Ah! Look!

P: It's like vinegar.

25 P: It's like water.

Ps: Yeah.

P: It's coming yellowish.

Ps: Yeah, yeah.

Ps: Miss, it comes yellowish.

30 P: I told you. Oh! Oh!

LL.2-16: S-b

Ps engaged in undirected investigation. They are uncertain about the results to expect. No direction from T.

LL.17-18: S-a

T acknowledges Ps' "good" observations, implying they are acceptable and important.

LL.24-29: S-a

Ps compare what is seen with characteristics of material previously experienced. They use descriptive, non-scientific language.

P: Bubbly.

P: Miss, it's bubbly.

T: Stir it. Close the burner, my dear.

P: Turn it. Just turn it. (P stirs and turns the dish.)

P: Ow!

T: What about the pot holder, Jacques?

P: It's your job now.

P: John! Do it!

P: Ah, ah, it smells good.

(Heard in background from Group I)

T: What about the spoon melting?

P: We stirred it with the spoon.

T: Well, why did that happen?

(Group 3)

P: They (referring to Group I) turned it with the spoon and the spoon melted.

P: That's why I don't want to turn it with the spoon.

P: Oh, no! That thing is hot.

P: 'Cause the spoon melted the ----.

LL.14-24: p-S-c

T's questions appear to request more than a description of events, but P replies with a description of what happened to spoon. T does not pursue explanation. Dialogue is too brief for definitive clue, but is a hint that T considers such descriptions adequate as explanations.

P: Hey, there's so little in the center, there.

P: Look at the syrup.

P: Yeah, that's what I was going to say.

P: Looks like maple syrup.

LL.28-31: S-a

Ps associate observations with familiar "syrup". Sense-data information derived from own experiences.

1 P: Hey, let's try to eat it.

P: Maybe it is.

Ps: Oh, ah! (Ps tasting drops of syrup.) Good.

5 P: It's sugar. (Ps giggling.)

P: Mine tastes better.

P: Sugar!

P: It is syrup. Ah, it's good.

P: It looks like toffee.

10 P: Yeah, toffee. (Ps laughing.)

P: That's probably how they make it.

P: Yeah. (Ps pulling syrup into strands.)

15 P: Ah, look it's like ----.

P: ---- like spider webs, when you pull it.

P: Oh, yeah.

P: It's like hair.

20 P: Not hair, but you know that plant there, that looks like ----.

P: Maybe spaghetti, sticky spaghetti.

P: Don't do that.

25 P: Oh no! (Ps giggling and pulling the strands of caramel sugar.)

P: Oh, Miss, it sticks.

T: What about you two?

30 P: Is it syrup?

P: A rope!

LL.3-10: S-a

Ps associate appearance of powder with other familiar foods.
Reference to prior, personal experience reinforces observations made.

LL.16-33: S-a

Ps use simple vocabulary to describe strands of sugar. They refer to familiar objects such as spider webs, hair, spaghetti.

P: Miss, it curls like syrup.

P: See, she said it is syrup!

T: I didn't say it wasn't. It's not funny. It's sugar you have in there.

P: Miss could we taste it?

T: Taste it.

P: Um, it's good. I want to taste.

T: Share!

P: It's good.

P: Um - we have something to eat.

P: We'll put aside some of it.

P: Okay.

T: (Claps hands) We have sugar in there. Try to think back children. Remember all our other observations. What happened with the water, the vinegar, the iodine? What happened when we mixed sugar? What happened?

P: It melted.

T: And -- .

P: It dissolved.

P: It didn't burn.

P: It didn't melt.

T: What did not dissolve?

P: The crystals.

T: Ah, and today?

P: The crystals melted. (Ps very noisily chattering, coughing, moving chairs.)

Ps: Ugh.

LL.1-6: S-a

Ps and T continue to talk about powders using simple descriptions derived from sensory perceptions.

LL.15-30: S-a

T refers to Ps' previous experiences. She asks them to recall observations made with sugar.
She accepts all comments without indicating which observations are more valid than others.

This implies that observations made during prior experiences are useful in understanding present observations of powders.

P: He loves it.

P: It tastes good but ---- .

T: Sh! Lower your volume.

P: ---- then after it became maple syrup.

P: It was candy.

T: I'm waiting for everybody to sit down. Sh! Sh! 4a! 4a! You're gonna miss the purpose of our observation. (Long pause) What is the first thing that you noticed?

LL.9-17: S-b and S-a

T implies that purpose of investigation is observation, and noticing as much as possible can generate important information about powders.

P: ---- the stuff around it dissolved.

T: For the first time today, what is it that dissolved the crystals? The -- ?

LL.15-p.A13, L.5: S-a

Among many observations collected, T implies that something of significance is worth remembering and listing.

Ps: Fire.

T: Fire. Any other ---- before ---- .

Ps: They were melting.

T: We could still see the crystals very nicely ---- but the crystals would remain there.

(Not possible to transcribe noisy P-P interaction as they nibble on the strings of caramel.)

LL.25-31

Classroom Management

T: Once your snack is completed, I wish we could have your attention.

T: You didn't have any Elan?

Elan: I didn't have any.

T: Maybe after, when we observe the next powder. We go to ---- for his first observation. (T writes on chalkboard.)

Sugar: The heat dissolved

1 the crystals.

All together.

Ps: (in chorus) The heat
dissolved the crystals.

LL.2-14: S-a

T checks to be certain that "all" Ps made valuable observations.

5 T: OK. We all observed that.
What did you observe after,
Elisa?

Elisa: ---- crystals.

T: You could still see crystals?

10 Ps: No. No.

P: No.

T: I didn't check yours. Are you
sure of that? Ask the others of
your group. Ann?

15 Ann: ----

T: Well, what does maple sugar
look like? (T shrugs shoulders.)
You can't say it looks like maple
syrup. Pauline, because -- ?

LL.16-19: S-a

T stresses need to describe appearance of sugar.

20 P: ----

T: OK. So do you agree, Ann?
Repeat again, Ann.

Ann: ----

T: Yes, flat, flat what?

25 T: Yes, Ann, then -- .

Ann: Then it dried up.

LL.21-27: S-a

T encourages P to provide descriptive information.

T: Uh, huh, then what happened
when it dried up? What happened
when the mixture ---- .

30 P: It came hard.

T: It became hard. Yes. (T
writes on chalkboard under the
first characteristic for sugar.)

LL.27-33: S-a

T solicits more sensory descriptions.
She records the observations implying that something of importance may be revealed by the Ps' observations.

: The liquid dried up.
It became hard.

Third group, before your powder turned hard there, where you could eat it, who remembered, who noticed if something happened before that, after the crystals had been dissolved?

P: It melted and it runs.

T: It melted and -- ?

P: It spreaded around.

T: It spreaded (sic) around, yes Chris?

P: It turned yellowish.

T: Yes, it turned it a yellowish colour, and we had a white powder. (T writes on board, continuing list of characteristics for sugar.)

: It turned yellowish.

Something else I did like to ---- .

P: Miss, he sits on the desk, instead of on the chair.

T: Please sit on the chair, my love. Sh!

P: Miss, it gets black like a beer bottle. It goes like the bottom of the beer.

T: Well that's the form it has on the plate. That's due to the container. It's not the heating that gave it that form.

P: Mine turned hard. The knife and the fork even stick on to it.

T: Yes, yes! You should have been able to tell me that. Yours was working beautifully when you had your fork there, eh? What happened to it?

LL.3-19: S-a

T solicits random observations and she accepts colour, again implying that certain important characteristics are derived from the observations.

LL.25-31: S-a

T's response to P's sensory description appears to be an attempt at an explanation but is a reference to what is seen.

L.34-p.A15, L.2: S-a

T indicates that P's observation is appropriate and she requests more descriptions.

P: Oh, Miss, it stretched.

T: It stretched, yes.

P: It looked like straw, sort of, when it was ---- .

LL.3-9: S-a

Ps talk about observations using simple, non-scientific vocabulary.

T: Sh, sh.

P: (Continuing) all that stuff on the fork. It looked like straw.

Ps: (all at once) Yes, straw, stretched, hard ---- .

T: Are we listening to the others?

P: When we lifted it in, it was all in - not one piece. When we shook it, it was just in one piece. But when we pulled it up, it started to get hard but it broke ---- just like that.

T: So how would you explain that? How are we going to write that on the blackboard? How are we going to write on the blackboard for our observation, for our notes, that sticking of our fork?

LL.16-31: S-c

T asks for explanation, but accepts sensory description of what has been experienced.

Ps and T use simple vocabulary, such as hard, stretch, stuck, terms Ps are familiar with.

T associates "explanation" with sensory descriptions.

P: It stretched.

T: It stretched, yes, and then -- ?

P: Then it turned hard.

P: And it broke.

T: It turned hard, yes. (T writes on board.)

: It stuck to the fork
and became hard.

P: It stretched. (Ps chattering noisily.)

T: OK. You can use your second number here -- . Use your powder 3 which is -- . (T hands out aluminium dishes. Ps all talking at once while putting powder into their dishes.)

Episode III: S-a

(L.32 - p.A25, L.22)

L.32-p.A16, L.10: S-b

| | | |
|---|---|---|
| 1 | T: Use your pot holder, or you will burn yourself. (T lights alcohol burners.) | cont'd... S-b<br>Ps carry out investigation without information from T as to amount of powder to use or results to expect. |
| | (Microphone taken to edge of Group I) | |
| 5 | P: It's turning now. | LL.5-10: S-a<br>Observations gathered through use of the senses.<br>Ps use descriptive vocabulary. |
| | P: It's funny. | |
| | P: It's turning brown. | |
| | Ps: Yeah. | |
| | P: It smells! | |
| 10 | P: It's brown and dark brown dots. | |
| | Ps: Yeah. | |
| | P: It's different than number 2. | LL.13-23: S-a<br>Ps compare observations with previous test results. Comparisons refer to sensory descriptions. |
| | P: Crystals aren't, ah ---- . | |
| 15 | P: It doesn't stick to the ---- . | |
| | P: The crystals don't go away. | |
| | P: Turning brown. | |
| | P: Yeah, it's turning brown, light brown. | |
| 20 | P: Brown as number 2. | |
| | P: It's burning! | |
| | Ps: In number 2, the crystals melted! | |
| | P: It's turning all, ah, crunchy! | LL.24-30: S-a<br>Ps use sensory, descriptive terms. |
| 25 | P: No, no, no! It's gonna burn again. | |
| | P: No, just a little bit. | |
| | P: It's gonna burn. It's all brown. | |
| 30 | P: It stinks! | |

P: Look, it's turning black. First it was brown, then it's black.

P: Stir some more. Stir faster.

P: First it's brown, then it's black. Who knows when it can be purple.

P: (Overheard from another group) Miss, they made a hole in it (refers to aluminium dish).

P: Eh, it's melting!

P: No, it's not melting.

P: It's turning all black. Black, white and black.

P: OK. Keep on turning and stirring.

T: Notice carefully this time eh?

P: It turns all black.

P: It's turning like those things that you put the fires ---- .

P: It smells.

P: It smells like popcorn.

P: No way!

P: Put it here. (P takes dish off burner, then replaces it.)

P: It smells worse.

P: The crystals aren't going away!

P: But it's going down all the time.

P: Wait! Stop the stirring.

Ps: It's crackling.

P: It's like popcorn.

LL.1-6: S-a

Ps' descriptions based on sensory observations. They have no preconceptions about observations.

LL.3 and 14-15: S-b

Ps' comments about stirring indicate they realize the need for care in handling powders during test. No instructions given by T.

LL.16-32: S-a

T suggests Ps notice what happens without suggesting what kind of observations to make.
Ps continue to rely on observations based on use of senses.

P: Yeah, leave it there.

P: Hey, Miss, ours is like popcorn.

P: It's crackling.

P: I know.

T: (To whole class) If you did talk a little bit less, we could hear ---- .

P: But look at it.

P: Hey, stop moving it.

P: It's not crackling now.

P: Yeah.

P: Maybe it's ---- .

P: Look it's all turned black.

P: You put a lot in it and it goes down every time.

P: Yeah, I know.

P: But the crystals are still there.

P: It's getting less and less every time.

P: Gina, look, it's getting less and less every time.

P: No, it's not popping. It stopped.

P: Yeah, I thinks it's gonna make a hole.

P: I'm sure.

P: Close the fire a bit.

P: Alright, not that much.

P: It's gonna be hot, to be real better (sic).

LL.2-25: S-a

Ps' observations refer to simple descriptions -- what is readily perceived as a result of random activity.

Ps use descriptive, non-scientific vocabulary.

LL.29-32: S-b

Ps realize need to control heat although no instructions given by T about test procedure.

P: No, it's not popping.

P: It's not melting, nor nothing.

P: It's not even melting. Nothing.

P: Miss, it's stopped popping.

T: It's not popping?

P: Miss, she put a lot in and everytime when she stirs it, it goes down a little.

P: She cools it too much.

P: It doesn't melt. The crystals stay there.

T: Ah! Uh, huh.

P: It doesn't melt, except it goes away!

T: Now think back at home there. What is this powder?

Ps: Salt.

T: Salt. Does mommy ever use salt for what? Think carefully.

P: She puts it in the soup.

P: In hamburgers.

P: In soup.

T: I don't mean to use it in the cooking, dear.

Ps: Oh! (giggles)

T: Think of what you're doing now. Think again.

Ps: It's gonna make a hole!

T: Does she use it for a fire?

P: Oh, they use it for fires on

LL.1-16: S-a

Ps' descriptions are a result of random sensory observations. Descriptions are accepted by the T (L.14).

LL.17-31: p-S-c

Appears to be an attempt by T to derive an explanation of the effect of salt on fire.

Ps do not follow T's questions and they refer to personal experiences with salt.

the stove.

P: Is that what your mother uses it for?

LL.4-13: S-a

Ps carrying out random observations.

Use simple non-scientific language.

P: I just find it funny.

P: Look everytime it goes ---- .

P: Hey, it's turning more.

P: It's down like that.

P: Don't worry about it.

P: Oh, don't close it, Benjamin! (refers to burner)

P: It's closing.

P: So what!

P: Careful!

T: Watch the wires please. (Ps passing back and forth across the wires of the recorder.)

P: It doesn't stick to the knife.

P: But the other one did, though.

P: I know.

LL.20-29: S-a

Ps use simple descriptive vocabulary to talk about observations.

P: Look at it. It's going away. (Ps stirring powder in dish, arguing about colour and smell, interrupting each other.)

P: It's not melting or anything. It's just staying there.

P: I know.

P: It's turning brown.

P: It's turning black, and brown.

P: It's turning green!

P: Gina! Look what she's doing.

P: Gina's gonna make a hole

under ---- .

T: Well, what of your noise! ---- after mixing it like that there. You think you're gonna leave it on much longer?

Ps: No.

T: What do you think would happen if we left it on? Do you think it's had enough now to have showed (sic) that it's, ah ---- ?

LL.7-18: S-a

T's questions refer to sensory observations.

P: Yeah.

T: Yes. What do we see that ---- ?

P: It didn't melt as number 2.

P: It kept on going in all the time.

T: What would it be good for then? What do you see there?

Ps: Crystals.

LL.17-28: S-a

Ps report random observations based on concrete evidence.

T: Well, look at it again.

P: Black crystals.

P: Yeah, black.

T: Let it cool off there.

P: Look at the plate.

P: It sticks to a spoon.

P: It sticks to a knife.

P: It must be allergic to knifes (sic).

P: The crystals are still there, everything.

P: I know.

P: Don't put it back on there.

P: Don't put it back.

LL.1-9: S-a

Ps discuss taste of powder.

Sense-data observation.

P: Well, keep it there.

P: Who wants to taste it?

P: Not me! You taste it.

P: Me!

P: Yeah, you're the one who tasted it before, too.

P: I don't wanna taste it.

P: OK. I'll taste it.

P: Same thing.

T: Oh. There she has it. It took you long enough. (Ps very noisy.) I think you should all sit down now. Class! Do we all have a chair?

Ps: Yes.

LL.19-33: S-b and S-a

T solicits results of investigation.

She accepts sense-data information as the results.

T and Ps use non-scientific vocabulary to talk about observations.

T: Well, sit. I see that some of you had problems with their stove. (T takes dish of powder from group I and shows it to group 2.) Observe this one. (Ps continue talking, moving chairs.) OK. What did you notice, Laura? Sh! Over here, there. Patrick!

Laura: We're working with salt.

T: With salt, fine. What is our first observationn? I can't hear you Laura.

Laura: When you put it in your mouth it melts fast.

T: I am talking about the heat test. What did you observe over the fire?

Laura: Um, there was - ah - black spots in it.

L.34-p.A23, L.3: S-a

T solicits identification of "spots".

T: And what do you think those black spots were?

Laura: They're crystals?

T: Okay. (T writes on the chalkboard.

Salt: The crystals turned black.

Did everybody see those black spots?

Ps: Yes.

P: Miss, the salt had crystals but these crystals didn't melt like the sugar.

T: OK. So sugar has crystals and the crystals melted. Salt has crystals and the crystals did not melt. We have to find out ---- Antonella?

Antonella: ----

T: (To noisy class) You cannot hear what the others are saying when you are talking. So you might have made different observations, but by listening to others we will all put our knowledge together.

Antonella: Ours turned yellow, white and black, sort of, all sorts of colours.

T: Well, what do you think made it turn different colours? You said it's the crystals that were turning. Why are some crystals exactly the same colours?

Antonella: Miss, the fire?

T: Right, on account of the fire. So the reason, I guess, that Antonella is giving us, is the crystals did not all turn exactly the same colour, is due to the intensity of the fire, eh? The longer you leave them, the darker they would turn. Over here, they had a hard time with their stove and you could only see a few crystals that did turn black. Just a few specks, see? (T shows children the dish of crystals.) Only a few. The rest will start to turn brown -- . (To

She accepts P's answer and assumes other Ps made same colour observation

LL.5-12: S-a

P makes comparison between present and previous observations. T repeats P's comment without providing information or explanation.

LL.16-19: S-a

T's comment implies that different observations made by Ps may contribute to knowledge by revealing important information.

LL.23-39: p-M-c

T's question appears to be a request for an explanation. P realizes that "fire" has some influence on colour of powder.

T provides the beginnings of an explanation which refers to more than sensory descriptions (LL.31-34). She relates Ps' experience and her own understanding by referring to the intensity of fire as a reason for the different observations.
T uses complex, theoretical term in explanation.
T's comment suggests the development of via media ideas.

class) Are you still with me?

Ann: Number 2, it melted ---- .

T: Sylvain would you be able to repeat what Ann just said? No, eh? So.

Ann: Number 2 ---- was all runny. It dissolved like water, then it got thicker. That one there just stayed the same way.

T: You're right.

P: With the salt, ---- everytime we were stirring it, it got smaller and smaller.

T: Um, and, what else did you say you heard when you were ---- ?

P: It popped.

T: It popped, yes. (T writes on board under first description of salt.)

: The crystals popped but did not dissolve.

P: But the crystals did not melt.

T: That's exactly what I have ---- . Read the second sentence. Boys and girls, can you -- Sylvain, can you read for me the second sentence?

Sylvain: The crystals popped but did not dissolve.

P: Miss, this, like, it came deeper, everytime you heat it. (P holds up his aluminium dish.)

T: Why? Because it is aluminium and the more heat you give to it, it, kind of, stretches out. Why do you think salt would be good then, if it doesn't melt? How would it be useful?

LL.11-17: S-a

T and Ps continue to talk about powders using sensory descriptions.

LL.17-24: S-a

T records descriptions again implying that many observations may result in something worth remembering.

LL.31-36: p-M-c

T's explanation, again, goes beyond sensory description. She uses own knowledge of effect of heat on aluminum and relates this to Ps' observations. This is development of via media ideas.

L.36-p.A25, L.11: S-c

P: Oh, ah, it could put out a fire.

T: Yes, yes! Salt would be very good to put out fires. Since you ---- over the fire there is no change. So of course if you took a handful of salt and put it on your fire, you can eliminate a fire right away. That's what I was asking Ann, before. Often your parents, when mommy's making french fries, if the oil or the grease goes over, there's a danger of fire. Pour some salt over it.

Ps: Oh, yeah.

T: Jean?

Jean: Before with the sugar, when ours broke (refers to the hole in the aluminium dish) well it made the fire even bigger. Made it bigger.

T: Uh, huh. We will go to our powder number -- .

P: Number 4.

T: We'll go to 5 and leave out number 4. (T hands out new aluminium dishes.) Children, powder number 5, number 5.

P: Miss, it's number 4.

T: Let's look at the time, OK? We will jump over -- we will skip powder 4 and we will go to powder 5. We've run out of time.

(Microphone is placed at edge of Group 2. Ps working with powder 5, heating the powder in the aluminium dish over the alcohol burner. Classroom noises are louder than group voices.)

P: Oh, please, don't record this.

T requests a reason for use of salt. This is a return to T's previous question (p.A19, L.20). P's answer is accepted as correct. T provides a functional explanation by referring to personal experience Ps may have had or can relate to.

T uses simple, non-scientific vocabulary.

LL.23-36

Classroom Management

Episode IV: S-a

(L.36 - p.A30, L.24)

LL.36-p.A28, L.8: S-b

Random P investigation of cornstarch. No T information regarding procedure or results to expect.

P: Oh, oh.

P: It's like ice capades. (P makes patterns in powder with a knife.)

P: It comes brown very slowly.

P: Don't put too much.

LL.7-15

Classroom Management

P: Let's have a turn. That's what teacher said.

P: Let's eat it.

T: Let others have a chance.

P: Teacher said let everyone have a chance mixing it. That's what teacher said.

P: OK. It's my turn. I want to try too.

LL.16-31: S-a

Ps collect as much sensory information as possible. They use simple, descriptive vocabulary.

P: It's becoming brown.

P: Can I try it?

P: Soon. Ouch! Soon you'll have a chance.

P: We're gonna make a hole ---- .

P: It stays white.

P: Yeah, but in the bottom it's beige.

P: It's only the bottom.

P: What's happening?

P: Because it's coming brown.

P: It's so soft. Touch it.

P: It's always soft.

P: It's smooth.

P: Is it hot?

P: It's smooth.

P: You want it? Have it.

P: I want to taste it.

P: Tastes better.

P: I know, but it's smooth and soft.

P: Ooh, it's coming brown.

P: Oh boy, there's a hole!

P: It's coming brown.

P: Oh no. Put that back. Put it back.

P: It's your turn. C'mon.

P: Miss, come and look here. It's smelling like burnt toast again.

P: It's coming too big now (refers to flame).

P: There's a hole in there.

P: A minute ago it didn't want to light up, now it's burning too big (refers to flame).

P: Wow, it's like magic!

P: Now it's closed. Closed completely (refers to damper of burner).

P: The fire's out. (T comes to group to adjust and relight burner.)

P: Ah, it tastes awful.

P: Yeah, but it smells nothing.

P: It smells burning.

P: Make a hole. Make a hole and let it fall in the fire.

LL.1-33: S-a

Ps talk about powders in terms of sensory observations, using non-scientific vocabulary.

Their observations are a result of their own experiences with the powders.

P: Look, it comes off.

T: All sit. OK. Children! Arthur, what was our 5th powder?

Arthur: Cornstarch.

T: (T writes word on chalkboard.)

Cornstarch:

I am waiting (Ps become quieter) to find out what you have observed in burning the cornstarch, Steven?

Steven: It's like crumbs of bread that were roasted in an oven.

T: Well, what makes you say that?

Steven: It's hard to ---- .

T: ----

Steven: Lumpy.

T: That's better. So, stirring it, what did you notice?

Steven: Stirring ---- lumpy ---- black on it. Some that stayed white.

T: Uh, huh. (T writes on board.)

Cornstarch: Stirring the
powder it becomes
lumpy and dark.

---- read Steven's first observation.

P: Stirring the powder, it becomes lumpy and dark.

T: Alright. That's the first thing we noticed. Then Antoine?

Antoine: ---- with the water and ---- .

LL.8-23: S-b and S-a

T requests results of investigation of cornstarch by referring to observations made.

Ps provide and T accepts descriptions of powder derived from use of senses.

Ps' observations result of their own experiences during investigation.

LL.24-33: S-a

T records certain observations implying that something of importance is derived from the random collection of observations.

T: Sylvain and John, please!

Antoine: With the water, the iodine and vinegar it always stuck to the bottom and here it doesn't. It sort of came like little pieces.

T: It became lumpy. That's the observation. Is it not sticking together? Well we have no liquid today. So it means that -- . What happened? Now did the powder remain? (T goes to one of the noisy boys and reseats him elsewhere.)

Antoine: It remained by itself.

T: What do you mean, by itself?

Antoine: It didn't stick to the aluminium.

T: It didn't stick to the aluminium, so the powder --. Was there any change in it?

Antoine: It turned brown and lumpy.

T: Just the powder. So the powder itself did not change. There was no dissolving like the sugar. The powder remained except for a change of colour and the lumps. (T writes on board under first observation of cornstarch.)

: The powder remained consistance (sic)

Anything else observed, here?

P: It wasn't sticky ---- .

T: Right, it wasn't sticky like the other times. The other times the liquid made the powder dissolve

LL.2-11: S-a

P compares observations made with same powder.

T solicits simple, descriptive term as observation.

LL.11-19: S-a

T solicits description of observations made, implying that these are important for understanding the changes that occurred.

LL.21-31: S-a

T's questions encourage P to make sensory observations.

LL.31-36: S-a

T records certain observations implying that random data collected may generate information worth remembering.

LL.37-p.A30, L.15: S-a

T and Ps refer to observations based on use of senses.

and today the heat did not dissolve the powder. It's exactly what we have just remarked.

P: When you ---- your teeth together, it sticks on the bottom of your teeth.

T: The powder? You've tried it? You tasted it?

Ps: Yeah.

P: Yeah. It tastes like popcorn.

P: It doesn't have any taste.

T: It's flat, OK.

P: ---- and when you bite it with your teeth, it sticks.

T: It had a flat taste and what did you say? It sticks to the teeth. (T writes on board, under observations of cornstarch.)

: Tasting it, it was flat and it stuck to the teeth.

LL.16-24: S-a

T gives no information about the powder. She records result of sensory perceptions implying that these reveal something of importance.

P: It has no taste.

T: We have one that we will not have time to do, which was powder 4. What did we have in powder 4?

Ps: (loud chorus) Icing sugar!

T: Icing sugar. Next week for science period, I will leave my burner here and we will try icing sugar. For now, very slowly and nicely you will return to your desks. I will leave the notes on the blackboard ---- .

(End of lesson.)

## SCIENCE LESSON - 05

## Seed Formation and Dispersal

(The lesson begins.)

Teacher: ---- bean plants, way back, a month and a half, two months ago, when we first planted them, what was the first part of the plant that we saw coming from the bean seed? Julia?

Julia: Roots.

T: The first thing we saw was a root, that's correct. What came next, after a few more days? We watched them and then we put them in the soil. What was the next thing that appeared? Chris? (Ps hands up.)

Chris: Stem.

T: The stem was the next thing. That is correct. And what was the third thing that appeared, about a week and a half later in those plants that survived? (Ps hands up.) Peter?

Peter: The beans, ---- the little things -- comes out.

T: Yeah, and what are those little things?

P: The seed coat?

T: No, not the seed coat. Chris?

Chris: Buds.

T: No, they weren't buds. Peter said one of the words. He actually said the word but he didn't say it ---- what was the third thing that came out? We had the roots, then the stem and what was the third

Episode I

(L.1 - p.A35, L.28)

LL.4-7: F-a

T solicits particular observations from previous activity.

LL.7-21: F-a

T ensures that certain observations are given in appropriate sequence.

LL.24-34: F-a

T expects Ps to recall particular observations made. These should confirm his expectations.

Ps' answers brief, uncertain. Suggest they are searching for acceptable answer irrespective of their own observations.

L.31-p.A32, L.11: F-a

T implies that observations are acceptable if these include certain information which is known and expected.

thing that appeared? Elly?

Elly: Leaves.

T: The leaves. Yes. So Peter was partly right because he mentioned the word leaves. And the plants spent some time growing. Most of them got quite tall. A lot of them died. What happened then to the plants that were healthy enough to survive? What happened next Sharon?

LL.11-41: F-a

T expects Ps to present certain information from their perceptions.

LL.11, 18

(T's question appears to be an "open invitation" for a description.)

Sharon: They started to grow some flowers.

T: Yes. They began to grow flowers. That was the last part that grew. Now what happened from the flowers? This is just recent history, things that happened in the last 2 or 3 weeks, depending on the plant. Natasha?

Natasha: They grew thin beans.

T: Right. Out of the center of the flower, on some of the plants, those of you who were lucky enough, beans began to develop. What happened to the flower itself? Paula?

LL.24-28: F-a

Actual observations made by Ps confirm what should have happened.

Paula: It turned into a bean.

T: That's correct. The inside of the flower became the bean. What happened to the other parts of the flower? Michael?

LL.33-41: F-a

Ps' observations are an obvious description of what seen. Confirm T's expectations. T's previous and subsequent questions are structured to derive certain perceptions.

Michael: They died.

T: Yes. They died and -- how do we know they're dead? Yes. They've fallen off. And what else have they done besides fall off? Allen?

Allen: The leaves turn yellow.

T: Yes. What leaves? What do we call those leaves that turn yellow? (Ps hands up.)

P: Stems.

T: No. You can use the diagram on the board if you want to. (A labelled diagram of the cross section of a flower is drawn on the side board.) What do we call those leaves that turned yellow and shrivelled up? Chris?

Chris: Petals.

T: Yes. The petals which were a sort of pinkish, light purple colour on our bean plant have shrivelled up leaving just the bean in its place. What did we say, in the very beginning, were the three most important parts of the plant? Sandy?

Sandy: The roots.

T: Right.

Sandy: Stem.

T: Uh huh.

Sandy: And flower?

T: No. Two out of three is not bad though. Neil?

Neil: The root.

T: Yes. Why did we not include the flower on there, when we were talking about the three main parts of the plant? Why do we not include flowers? They are certainly important. James?

James: It's not part of the plant.

T: It's not part of the plant. Um. Can you say more than that

LL.1-12: F-c

T expects Ps to use particular label for "those leaves". T considers "petals" to be correct suggesting this is the answer he expected.

LL.5-9: F-c

Diagram serves to focus Ps' attention on appropriate terms to use when talking about plants.

LL.17-29: F-c

T structures questions so that certain information is provided.

Answers must confirm T's expectations (LL.25-27) irrespective of Ps' understanding.

Michael?

Michael: Well, because the flowers are only used once a year for pollination, but the plant stalk grows all year.

T: That's correct. The other 3 parts are permanent. The root, the stem and the leaves remain all year, or most of the year, depending on the kind of plant. But the flower only appears at certain seasons. Why else is a flower not so important?

P: The flower gives the plant beauty, or something like that.

T: It certainly makes it beautiful on some plants, but there is a reason why it's not so important. Chris?

Chris: Because the leaves, roots and stems feed the plant but the flower doesn't ---- .

T: Very true. The roots, the stem and the leaves are responsible for keeping the plant alive combined together, but the flower doesn't. Is there any part of the plant that we could cut off that would make no difference to the plant, to its life span, how long it lived? Sharon?

Sharon: The flower.

T: If you cut off the flower, what would happen to the plant? James.

James: Grow a new one.

T: Yeah. You'd grow a new flower or what else might happen? Chris.

Chris: ----

T: Pardon me? You're right

LL.2-5: F-c

Michael's account is derived from science information given during lesson, not from his own experience.

LL.6-13, 17-19, 23-31: F-c

T uses carefully structured set of questions and statements so that acceptable information is provided, which he expects, irrespective of Ps' accounts.

LL.33-39: F-c

James refers to his own experience, but T expects a particular answer.

(The vagueness of the T's question (LL.33-35) may account for the random effort by Ps to understand what is expected.)

there. Allen?

Allen: Like ah, when you cut it, you put it in this water, in a glass or something, and after about a week you're going to see some stems, I mean some roots.

T: Oh, that's if you cut the plant. You could save it by putting it in water. But what happens if you cut off the flower, not the leaves, or the stems, or the roots, just the flower. Sharon?

Sharon: The flower would die.

T: The flower would die. Is there anything else that will happen to the plant? Michael?

Michael: No.

T: No. Nothing else will happen to the plant. It might grow a flower somewhere else. The worse that'll happen is that it won't have any offspring. It won't have any seeds. And that's not going to make any difference to the plant itself. I don't think plants know when they have seeds or not. Now, what happens inside the flower, then? Let's say we've got a flower on our plant, what must happen to the flower, James?

James: Well, um, ah the anther --?

T: It has to do with the anthers, yes. Chris?

Chris: You have cross-pollination and self-pollination.

T: OK. So the first thing that must happen is pollination eh Chris? And there are two types. What is pollination?

LL.2-12: F-c

P's comment based on his own experience, but T structures question to derive particular information, implying P's answer is not what he expected.

LL.14-26: F-c

T's comments suggest that his knowledge is more important in understanding about plants than Ps' experiences.

Episode II: F-c

(L.28 - p.A42, L.2)

LL.28-32: F-c

T's question cannot be answered by reference to experience. Question is request for prediction. Answer depends on science information.

LL.41-p.A36, L.9: F-c

T's question requires certain science information. Cannot be derived from experience.

Elan?

Elan: When the anthers break and release what's inside them and then it goes on a stigma and then after you're gonna have some bean pods, I think.

T: Oh. That covers it pretty well. What is this material that comes out of the anther, that breaks out, or blows off? Chris?

Chris: Pollen.

T: It's pollen. And what word comes from that?

P: Pollination.

T: Pollination. And Chris said there were two types. Chris, can you explain the two types of pollination for us?

Chris: There is self-pollination ---- .

T: OK. The pollen from one anther goes on the stigma inside the same flower. And what's cross-pollination, Chris?

Chris: When the wind blows it or when a bee picks it up and takes it to another flower.

T: Good. It's either carried by a bee or the wind and the pollen ends up in another flower. And which would be a better kind of pollination? Tony?

Tony: Cross.

T: Cross-pollination. That's correct. What happens once the pollen is on the stigma, because then pollination has taken place? Two things have happened. First pollination and what's the second one, Karen? What has to happen

LL.2-8: F-c

P's explanation includes science information expected by T. Information not derived from P's experience.

LL.9-31: F-c

T focuses questions so that acceptable information is provided.

He insists that Ps use scientific terms in their explanations (LL.8, 13).

T's explanation includes science information derived from own knowledge. Appears to be rules or definitions for understanding pollination (LL.22-24, 29-31).

Explanations given by Ps not derived from familiarity. Are limited to science information acceptable to T.

LL.31-33: F-c

T's question is a request for a judgement. Not in P's experience. Implies that T expects Ps to rely on science information in order to explain process.

to the pollen once it gets onto the stigma? (T holds up a small model of a flower with the cross section of the pistil visible.)

Karen: ----

T: Peter?

Peter: It grows seeds.

T: Well that's what's going to happen at the end. We're not quite there yet. There still has to happen one more thing. (Ps waving hands.) Anyone in this row got any ideas? What has to happen once the pollen lands in the stigma? (Ps: Oh, oh.)

P: It makes a tunnel down to the middle of the flower.

T: That's right. How many parts were there in the pollen grain, Paula?

Paula: Two.

T: Two. The first one does what? What is the job of one of the pieces of pollen?

P: To form the tube.

T: Right. Form the tube. And where does the tube go?

P: Down to the ovules.

T: Yes. It goes down inside the plant. What do we call that wide part of the flower? Ina?

Ina: The ovary.

T: The ovary. And what's inside the ovary Sandy?

Sandy: The ovules.

T: The ovules. And what

LL.2-4: F-c

Model of flower directs Ps to certain science information needed in explanation.

LL.17-19: F-c

P's explanation confirms T's expectations. Derived from science information given, not from P's experience.

LL.19-37: F-c

T structures questions so that set of rules evolve which refer to acceptable science information.

Ps' explanations derived from science information given previously.

happens then? Once the tube has grown down, what happens then, to finish this whole thing off? Sharon?

Sharon: The pollen splits.

T: Right. The remaining piece of pollen goes down the tube and joins up with one of the ovules inside. Now what do we call that process? It's also got a very long name. The first one pollination and the second thing has to happen when the pollen moves down inside and joins up with an ovule or egg. What do we call that one? (T writes on the board.)

1. pollination
2.

The first one was pollination and the second one, Paula?

Paula: ----

T: That's a good word to know. We'll answer that question in a few minutes but before we get to that, only one person remembers. Allen?

Allen: Fertilize. Fertilization.

T: Right. Fertilization. (T writes the word fertilization under pollination.) It's the second thing that has to happen. Now what do you call the whole process when you put these two things together? And these two things are the whole reason why plants grow flowers at all. What do you call them when you put them together? Clement?

Clement: You get a seed.

T: You get a seed. Correct but what do we call that process that gives seeds? Not just in

LL.1-30: F-c

T's structured questions and statements builds formal explanation of process of fertilization followed by reproduction (p.A39).

Ps' single word answers imply incomplete understanding of scientific terms provided.

LL.16-23: F-c

T focuses on scientific terms, which are known and acceptable.

LL.29-43: F-c

T expects Ps to use scientific terms.

P's reasonable answer is his own interpretation (L.40). T requests certain, acceptable scientific term.

plants, but the same word goes for animals, people.

P: Reproducing.

T: Right. Reproducing or reproduction. (T points to the words pollination and fertilization on the board.) Those together are called reproduction and without both, nothing will happen. (T adds the word reproduction.)

1. pollination    reproduction
2. fertilization

You have to have both. OK. That brings us up to date pretty well. And I think we mentioned, at the last science lesson, what happens inside the flower when reproduction takes place. Someone in class said this morning that the petals fall off or shrivel up. What else happens? Sharon?

Sharon: The seeds get bigger and bigger.

T: The seeds begin to develop inside. If they are very small when fertilization takes place, they begin to enlarge and develop. What else happens? James?

James: The anthers die in the plant. The petals close up.

T: Right. The petals in some plants close up or sometimes shrivel up. That is correct. The anthers die and what happens inside meanwhile, Allen?

Allen: The ovary gets larger and larger.

T: Yes. The ovary begins to develop into the shape that we're used to, such as a banana or a cherry or a peanut. Various kinds of seeds that we see and know about.

LL.4-14: F-c

T focuses on scientific terms which fit his understanding. Explanation given in terms of a rule or definition.

LL.20-40: F-c

Ps' explanations limited to science information rather than from their own experience.

Information fits T's expectations and his understanding.

T does not expect Ps to expand their explanations. (This implies that Ps have a limited understanding and need T's rules to help them account for events.)

Chris: Onion.

T: An onion, Chris? ---- Michael?

Michael: An onion grows in the ground.

LL.3-7: F-c

P refers to his own experience, but T requires certain information.

T: Some seeds grow in the ground too, of course. But there's something wrong with that answer. Yes?

Clement: ---- scallion.

T: Scallion? That's a new one to me.

Clement: Scallion. Tastes like an onion.

T: Does it? What's it look like?

Clement: It's long!

T: Oh. I see. Like leeks, I guess you'd call them. Well, what's wrong with onions? Why shouldn't we include onions in this discussion?

Clement: Onions don't grow seeds.

LL.21-34: F-c

P's comment refers to his own experience (L.21).

T presents explanation derived from his own understanding even though he is uncertain of the information.

T: That's right. Onions are more a root type thing underneath the ground. Onions don't grow seeds. Onions will sprout, but they don't have seeds inside them.

Clement: Then how do they grow?

T: Well, the onion plant has seeds, I was wrong, but the onion is more of a root or bulb that grows and makes the plant. But it's not the seed, as far as I know. Yes?

P: What about bananas?

T: What about bananas?

P: They don't have any seeds.

Ps: Yes they do.

T: Sure. Where do you see banana seeds? Michael?

Michael: Not at the top but at the very bottom there's very little tiny seeds.

T: Yeah. But not just at the bottom, though. Allen?

Allen: When you peel a banana and you bite into it, in the center there's little black things. All those little things are seeds.

T: That's right. There must be thousands of seeds in there, I guess. Take a banana, next time you're having one, Allen, and cut it lengthwise. Cut it down the middle, not across, but lengthwise and look inside and you'll see a dark yellow strip inside with a lot of white and black things. Those are the seeds. Chris?

Chris: Then we eat it when we eat the fruit. Fruit's food.

T: Yes, most fruit is seed. Most of what we call fruit, anyway, have seeds in them. But not all our food comes just from the seed. We also eat the stalks in celery, roots. We discussed that before (Ps hands up.) Now. Allen?

Allen: When we eat a banana, or something, we eat millions of the, ah, hard stuff, that once, like it's food. And then we're eating that.

T: The plants make enough extra bananas. Even if we eat most of them there's still a few of them to make new bananas. That's why there's so many.

LL.2-24: S-c

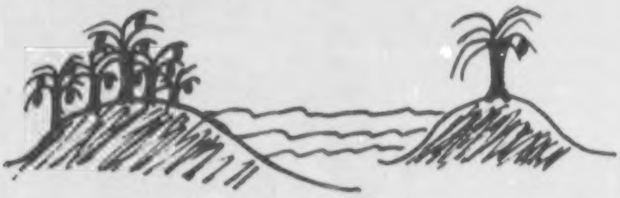
T's comments refer to Ps' experiences. Ps provide descriptive explanations as a result of their own familiarity with fruit.

T does not add information which is not in Ps' experience. Ps' comments considered important.

LL.25-39: S-c

Ps' comments refer to what they know and have experienced, T's explanation is not based on theoretical knowledge. It is related to Ps' own concrete experiences.

Now. We've got to the stage now where our plants have seeds. (T raises a map, that had previously been lowered over the chalkboard, revealing a coloured illustration.)



Does anyone know what kind of tree this is supposed to be? (T points to clump of trees on left of illustration. Ps hands up.) It must be a pretty bad drawing if you don't recognize it. (Ps: Oh! Oh!) What is it?

Clement: A coconut tree.

T: Thank goodness. OK. I don't know how accurate it is. I've never seen a coconut tree myself. It's a pretty close guess. Yes?

P: Because they're shaped like a football, not round.

T: Yes. Coconut fruit of that size have a football shape, more football shape than round. Now I want you to look at this little island over here, and it's got a number of coconut trees on it, which have fruit or coconut. The flowers have died, shrivelled up, and the coconut seeds are left behind. What's going to happen to those seeds now?

Ps: Oh! Oh!

P: They get bigger.

T: They might grow a bit bigger. Once they get to full

Episode III: F-c

(L.3 - p.A53, L.5)

LL.7-20: F-c

T's drawing serves to focus explanation so that certain information is derived. Drawing is based on T's understanding but not from his experience. And not related to Ps' experience.

L.15. P familiar with coconut tree.

L.23-p.A43, L.3: F-c

T's comments reflect own science information.

T's questions require certain science information. Not in Ps' understanding or experience.

L.35. P's answer logically derived from information in lesson.

size, once they are mature and ready to fall off, what should happen?

P: Pollination?

T: No.

P: I mean, ah. (Other Ps: Oh! Oh!)

T: It is after pollination, after fertilization and the seed is completely formed.

P: Reproduction.

T: Reproduction has already happened too. These round things you see hanging are the seeds. The seeds are inside the coconut. What should happen? Clement?

Clement: Well, after, the coconuts will fall off the tree and hit the water.

T: They might. The coconut is definitely going to fall off. Now do you know how many coconuts grow on the trees?

Clement: I don't know. Because sometimes there are three big branches and coconuts like mad!

T: So you'd say many coconuts.

Clement: Yeah.

T: OK. Chris?

Chris: ----

T: And how many coconuts would you say grew on your tree?

Chris: Twenty.

T: Twenty. OK. Clement says even more. So a lot of coconuts. There are 4 or 5 trees on this

LL.4-17: F-c

Ps use scientific terms with no link between term used and understanding of the term in the context of T's questions.

LL.18-36: S-c

P provides descriptive information from his own experience.

T uses P's experience as a clue to find out more information.

P describes what he believes to be the case (LL.25-27).

little island and they're all going to drop their coconuts, because the coconuts are already mature, and ready to fall off. Now what's going to happen to the coconuts when they land on the soil?

Clement: Nothing.

T: Michael?

Michael: Either they'll roll on the shore or roll into the ocean.

T: They might.

Michael: Or fall on the ground and um - I don't know.

T: Let's take the ones that fall on the ground. It is possible that some might roll down the beach into the ocean. Look at the ones that fall on the ground. What might happen to them? Andrew?

Andrew: Little trees gonna grow.

T: Oh. Technically speaking and hopefully, if everything works out well, seeds should begin to sprout and you should get small coconut trees. Do you think there could be any problems on that particular island? When you think that there might be 20-100 coconuts falling off a tree. What do you suppose can happen? Fanny?

Fanny: There's gonna be too many trees on the island.

T: And what's gonna happen as a result of that?

Fanny: And when the other trees grow coconuts there's going to be more trees and there won't be enough room for all the coconuts.

LL.1-32: F-c

T structures questions so that certain acceptable information is provided.

LL.10-15

P's first account is plausible. T's limited acceptance leaves P uncertain.

LL.16-32

T focuses on certain information. Implies that account of "what might happen" depends on information given.

LL.32-p.A45, L.22: p-M-c

Fanny appears to recognize connection between T's comment (LL.30-33) and what she understands from the lesson. Without personal experience, P provides reasonable prediction by relating science information to new event.

P's development of a via media view of explanation.

1 T: You say there won't be
enough room. What does that mean,
there won't be enough room?
Michael?

5 Michael: Because if you have
too many on one island, say the
trees here are full of coconuts,
and a coconut falls right here
and starts to roll and before
10 that all of the other coconuts
have a head start and they grow
and he's just starting to grow,
what happens is they would block
out the sunlight and he can't
15 grow.

T: Very good answer. One
thing they won't get, the young
trees, if the coconuts do sprout,
they won't get enough sunlight
20 and that'll make them eventually
die and certainly not grow to
a full height. What else might
happen? Chris.

Chris: They won't get any
25 flowers ---- .

T: Sure the big trees have
been there for years with great
root systems growing into the
soil. They won't get a share
30 of the water. What else might
they be missing? They won't
get enough sunlight. They
wouldn't get enough water.
And what's the third thing,
35 James?

James: They won't have room
for the roots to grow.

T: Right. And what are the
roots after?

40 James: The roots are after
the earth.

T: Right. And what's in the
earth? Paula?

Paula: ----

LL.1-22: p-M-c

T's question (LL.2-3) requests clarification of P's answer.

LL.5-15

Michael's answer suggests he relates new problem (re coconuts) with prior information about seed crowding. He has no personal experience and uses non-theoretical language.

P's own development of a via media view of explanation.

LL.16-35: F-c

After approving of logical answer (L.16), T requests certain information.

T repeats Michael's account implying that this is what he expected.

LL.36-43: F-c

T uses structured questions to solicit certain information which he expects.

T: If they can't make enough food it's because there's something missing in the soil, which we talked about.

P: They're missing minerals.

T: Right. Minerals. What do they need those three things for: sunlight, water and minerals? What do they need them for, Andrew?

Andrew: To survive.

T: Sure, to survive, but what we call -- what part of their life do they need those three things for: sunlight, water and minerals to help them survive? Ian?

Ian: Reproducing.

Ps: Oh! Oh!

T: Eventually reproducing but there's something else. Something more important than ---- Sharon?

Sharon: To stay alive.

T: Yes. They can stay alive. There was a process we studied that required those three things. Peter.

Peter: Food.

T: It has to do with food. That is correct.

Peter: To make them grow.

T: To make them grow. What's the word?

P: And there's, ah, like in the leaves there's some juice. I don't know, ah, pollen, the yellow thing.

LL.1-17: F-c

T directs questions so that certain information is provided.

LL.18-34: F-c

P's use of scientific term suggests uncertainty of meaning in context of the question.

T solicits more acceptable information.

(Implication that T's own understanding is more important in explaining events that Ps' ideas.)

T: No you're getting mixed up. Not pollen. What's in the leaves? It's all part of this word I'm looking for. Andrew?

Andrew: Starch.

P: No. (Ps vigorously waving hands.)

T: They might make starch in the leaves. They might make starch. Sandy?

Sandy: Chlorophyll.

T: Chlorophyll. And what is the chlorophyll involved in? It takes the water, the minerals and sunlight and what does the chlorophyll do with them?

P: Makes the food.

T: Makes the food, sugar. What do we call that process?

P: Photosynthesis.

T: Good. Photosynthesis. It's a while since we talked about that, I guess. (T writes word photosynthesis on the board.)

Ps: Photosynthesis.

T: And if the seeds were to fall in amongst, if these coconuts were to fall in among these trees, photosynthesis wouldn't work too well because there wouldn't be enough water and there wouldn't be enough minerals to go around for all the trees. OK. Now we're coming to something else that ---- brought up. What might happen to some of the coconuts? Neil.

Neil: ----

T: Yes. This one might land here and if it's on the slope of

LL.1-21: F-c

T solicits certain science information irrespective of Ps' reasonable answers (LL.5, 11, 17).

T focuses on specific statements or questions until acceptable term is provided (L.20).

LL.26-37: F-c

T's explanation includes acceptable information derived from own knowledge -- given as a summary.

T's request for explanation depends on science information. Not related to Ps' experience.

1 a beach or a large wave comes in,
he might end up in the water.
Now how does that ---- what's
going to happen next then?
5 Andrew?

Andrew: He's gonna, if he gets
all the way over, he's gonna grow
a tree over there. (P points to
island on right of illustration.)

10 T: OK. Do you think that would
be better than staying behind on
this island? Andrew, why would
it be better for that coconut, if
it floats?

15 Andrew: Because then he has more
room, because there's only one
tree ---- .

T: Exactly. Now for this
coconut...

LL.6-18: F-c

P's explanation is repeat of information given earlier by Fanny (p.A44, LL.34-41).

T's question is a request for a judgement (LL.10-12). P's comment limited to science information given.

20 P: How did that tree get there?
(P refers to island on right side
of illustration.)

T: How did it get there? The
same way that this coconut's
25 gonna get there. It's going to
land in the water and, luckily
for coconuts, they happen to
float, and...

P: How did the other island
30 get all them then?

T: I guess lots of coconuts
floated from elsewhere. Don't
forget, once you have one tree
dropping seeds, the first seed,
35 the first generation can stay on
the island and grow. It's only
after the island gets crowded
that they have to leave.
Michael?

LL.20-39: F-c

P's apparent lack of understanding tends to support idea that T directs explanations through his own knowledge rather than through the Ps' understanding.

40 Michael: How did the seeds from
there get over there? They'd
have to jump over the hill.

T: No. How did they get there?

Troy?

Troy: The wind?

Ps: No. No.

T: The wind might. Clement?

Clement: Big waves.

T: Big waves will push them. Sure the tide, current, and just rolling by itself. It's not guaranteed it'll get to this island, but it might have a chance of landing on an island somewhere and being pushed up, by a wave, onto the beach for it to begin to sprout and grow and as Andrew told us, if it grew here it would have a much better chance because it would have a chance at the sunlight and it wouldn't have to share the water with so many other trees. So it would have a chance of growing while the ones that fall in between here (T points to clump of trees on island) might find themselves not being very healthy. They might not grow at all. Now this is not such a chancey business as you might think. Nature has planned it this way over the years that certain plants spread their seeds around in different ways. What part of nature helps to spread that particular kind of seed, the coconut seed around? What part of nature did the tree use to get the plant to spread its seeds around? Chris.

Chris: Cross-pollination.

T: Oh, after pollination, once the seeds were grown. How did the plant use something that's already there, in nature, to move the seeds? Sandy?

Sandy: The wind?

LL.5-35: F-c

T does not refer to Clement's experience. T focuses on formal explanation which appears to be a review of science information given during lesson.

Explanation appears to be result of deductive reasoning.

LL.35-p.A50, L.15: F-c

T requests certain information. Ps' answers imply they do not understand what is expected.

P's use of term (L.39) suggests no link between term used and understanding of term in context of the question.

T: It might have used the wind.

P: No.

P: I think it's the weight, like the weight when it comes big, well of course it's gonna fall from the tree. Where it is, it's gonna die, gonna get loose and it's gonna fall.

T: Then nature designed the coconut, because of their weight, to fall down on the soil. What part of nature does it use to get the seeds spread around?

P: The water.

T: The water. Sure. Nature makes sure that plants spread their seeds around. Why do they want to spread their seeds around? Allen.

Allen: So there's more trees that would grow and there will always be some.

T: That's right. Plants want to ensure that there's gonna be more coconut trees around, more dandelion plants around or more of whatever it may be. So it spread the seed around --. Now the word I want to give you today is this word (T writes dispersal on board.) and someone with their hand up can tell me what they think it is.

P: Dispersal?

T: Dispersal. Does anyone have any ideas what dispersal is all about? Using what we have been talking about so far, what do you suppose the word dispersal might mean, James?

James: ----

T: Not quite. It has to do

LL.3-15: F-c

P's reasonable comment is repeated by T. Implies explanation confirms T's expectations.

LL.20-28: F-c

P's answer is reasonable in light of information given in lesson.
T uses information in a formal summary.

LL.30-42: F-c

T uses new scientific term and asks for interpretation by suggesting Ps refer to information given.
Implication that understanding of term is based on science information given in lesson.

with that but not quite that answer. Yes, Clement?

Clement: Spreading.

T: Very good. It means spreading. (T writes spreading on board under word dispersal.) We're discussing today seed spreading or seed dispersal. Now all plants produce seeds and they want to make sure that all the seeds don't all land on one spot for the reasons we talked about: not enough water, not enough sunlight, and so on. So they make sure the seeds are dispersed. What I'm interested in today is can we figure out the various ways that plants make sure their seeds get spread around. We've seen why the coconut tree uses water. Yes?

P: But one thing, isn't water, like it isn't pure, it has an awful taste. It's salt water. How can a seed grow in water?

T: Oh. Yes, I think you are confused. You're right that is salt water and I don't think the coconut will grow in salt water for very long. But it's not going to grow in the water. Where is it going to grow?

P: There's water inside the coconut.

T: Yes, there's water and milk inside. That's true. But there is an outer shell on the coconut and inside the seed is protected. Now where is the plant going to eventually grow?

P: Well, in the soil.

T: In the soil. Yes. It's not going to grow in the water. It's protected by a thick coat

LL.4-21: F-c

T accepts P's non-theoretical answer. Confirms T's expectation.
T provides explanation (rule) derived from his own knowledge.

LL.16-20: F-c

Suggests that T's preconceptions determine direction of questions and explanations.

LL.23-45: F-c

T's explanation derived from own theoretical knowledge. P cannot reconcile what he knows about salt water with T's explanation.

(Implication that T's understanding is more important than Ps' experiences.)

and when it gets on the land, it might begin to sprout.

P: I know, but, well when the water, like, it isn't, if there's a little bit, like in the dirt, like there's got to be something.

T: Sure. There's water there.

P: When the roots go down, there, they're gonna eventually touch the water.

T: We hope there's fresh water on the island, from rainfall. It can't use the salt water very well. It certainly can't use the salt.

P: I know that.

T: But it can use the water that falls in the rain.

P: Can the salt go through the soil?

T: Uh huh. Yes. I guess the soil will filter the water a little bit. But it'll probably use fresh water from the rain that would fall on the island. Michael?

Michael: If the other plants could just stick all their roots out of the island, then they'd have a lot of water.

T: That's for sure. Yes, they're surrounded by it. Andrew?

Andrew: Somebody said that the roots stop growing as soon as they get to the water.

T: Yes. The roots don't grow forever. As soon as they get to water that they need, a sufficient supply, they will stop. That's

LL.3-27: F-c

T's explanations derived from own knowledge, but not related to P's experience. (P's confusion persists and he continues to refer to his own understanding.)

L.28-p.A53, L.1: F-c

Irrespective of Ps' comments, T's understanding and expectations prevail.

true. Now, we looked at this case here. One way in which seeds are spread around or dispersed is by water. (T writes 1] water on board.) Now I'm going to give you a stencil which I want you to look at. Look at the various seeds on here and see if you can figure out how the plant uses nature to spread these seeds around. Think about it and look at the seed, think about how the plant uses nature. ---- will you pass those around this area and ---- pass these around here, please? (Stencil passed around. Appended at end of lesson transcription.) Clement, ---- . I've put the names of the seeds next to them. That shouldn't give you any clues. Shouldn't really help you at all in most cases. There's one, I think, might. Can you see, on the stencil, one type of seed that also uses water as a natural way of getting the seeds spread around? The coconut was one, so I didn't put it on here for you. There's another one that also uses water to help carry the seeds away from the parent plant, because the parents don't want to be crowded and --, Andrew?

Andrew: Bulrush.

T: Pardon me?

Andrew: The bulrush.

T: Ah, why do you say that?

Andrew: Because it grows in the water.

T: OK. The bulrush might, but it actually depends on another force in nature. It might use water to some extent, Andrew, but

Episode IV

(L.5 - p.A68, end)

LL.8-37: F-c

T structures Ps' observations by providing clues in the diagrams.
Work-sheet, then, limits Ps' observations so that certain expected information is found.

LL.25-35: F-a

T's question limits Ps' observations to particular clues irrespective of Ps' own perceptions.

LL.40-47: F-a

T expects Ps' observations to derive certain information which he expects.

P: So the seeds won't fall and if the little boat tips over.

T: If it tips over, if a wave hits it, or the wind blew. Yes. Why would it not want the seeds to come out though? Isn't the whole idea so the seeds will be spread around?

P: So it wouldn't fall out.

T: Well, wouldn't you want the seeds to come out eventually? Allen.

Allen: Like, when it grows, it's gonna eventually grow through the holes, but it won't -- the shell will hold it back from the seed. So it won't pop out of the seed. So when it grows, they won't come out of the hole. (Ps: Oh! Oh!)

T: That could be one reason. It's not the reason though. Yes?

P: Maybe till they start to grow bigger.

T: Well, if the seeds got bigger, they would have even more trouble getting out of the holes. The holes are too small already. Clement?

Clement: Well, when the seeds grow up they need some place to grow. If the seeds are in the water, you can't get the earth in the middle of the water.

T: But the seeds are not going to grow in this boat. How are they going to get out to grow, Sandy?

Sandy: When they are supposed to grow, they grow all together. (Ps: Oh! Oh!)

T: Well what would that do? They are all inside this shell,

LL.1-19: F-c

Ps' comment shows logical reasoning but it is not what T expects.

T structures questions so that acceptable explanation is provided.

L.20-p.A56, L.14: F-c

T continues to solicit explanation about size of holes.

Questions require a particular "reason" (L.21).

Ps' comments suggest limited understanding. They search for explanation acceptable to T.

LL.34-37: F-c

Question requires information known to T but not to Ps.

there's another one that definitely uses water. There's a little clue there that gives it away. (P: Oh! Oh!)

P: Lotus.

T: The one in the top right hand corner? Yes. The lotus. How do you know it uses water to spread around?

P: Because there is water under it.

T: Yes. It's a very easy clue there. It's got some water right past it. Now, this is an interesting kind of plant. I'll pass a book around later on to show you a better picture than my drawing. The seed grows inside a hard little shell like a boat and what you see is the top of this little shell. Mike?

Mike: ----

T: No. There are seeds and something else. Maybe you can't tell from my drawing. One of them -- yes?

P: And roots.

T: No. On the one that's floating in the water. There are seeds and there are little holes on top. The funny thing is that the seeds are bigger than the holes. Why do you think that plant grows a little boat, full of seeds, with holes for the seeds to come out, obviously, or you would think so, but the holes are too small. Why would they do that? (Ps: Oh! Oh!) It's hard to tell from my drawing. When I pass the book around you'll see what I mean. Why are the holes smaller than the seeds?

LL.1-7: F-a

Ps' observations are expected to confirm T's expectations.

LL.7-14: F-a

T's question refers to what P can see in diagram. P relates water with dispersal because water is the clue, not because P is familiar with lotus plant.
No explanation is expected.

LL.18-29: F-c

T's explanation is derived from information not observable in diagram.

LL.29-44: F-c

The fact that the holes are smaller than the seeds is not observable. An explanation is requested.
Information is not in Ps' understanding or experience.

like in a salt shaker except the salt is bigger than the holes at the top. (Ps: Oh! Oh!) Why would nature plan it that way, Sharon?

Sharon: ----

T: Yes, but they need more than rain. They also need soil sooner or later. It wouldn't be very good if they grew inside there with no soil. (Ps: Oh! I know!) It's true, if these do expand they might do something. Yes, James?

James: If it, like, tips over and all the seeds would fall out.

T: That's what you might think, but don't forget, the holes are smaller than the seeds. The seeds can't tip out. (Ps noisily commenting and raising hands.)

P: Oh, you mean it's inside.

T: The seeds are inside. Like in a salt shaker.

Ps: Oh, oh, I know.

James: ---- when it hits something.

T: There's the answer. Eventually this little boat will break up, either by washing, by floating in the water or by hitting something like James said. Or an animal might step on it or, pardon me?

P: ---- .

T: Something might step on it and crack it open. Then the seed would come out. Why would nature plan this particular seed like that? Why not make holes the right size for the seeds to

LL.3-24: F-c

Question requires information which Ps do not have.

T's explanation is derived from his own understanding.

LL.28-41: F-c

T provides information which is not in Ps' experience. (James' comment (L.26) not heard but might be a "lucky guess".)
T's information is derived from his own science background.

L.41-p.A57, L.16: F-c

T's questions require certain

fall out or make the holes bigger. Why not?

P: Because ---- .

T: That's true too if there's an animal, there is some kind of land close by. Another reason?

P: Well, mother nature put it like that because birds or something, maybe birds or animals would come and try to get the seeds.

T: Oh, I see, you mean to protect the seeds. That's true. Why not make the holes the right size or even bigger so the seeds would come out right away, Ian?

Ian: Because when it's on the water, the thing might tip over and the seeds would fall out.

T: Yeah. One thing I should tell you, by the way, the lotus plant grows in water. It grows in ponds and so on. Now. It would be OK if the seeds turned upside down, fell out, went to the bottom, because that's where the darn things grow to begin with. Now. Why make the holes smaller? Michael.

Michael: While they're in there, they need the roots and to be fertilized.

T: No, that's all happened already. These are full grown seeds and they are ready to start growing. Andrew?

Andrew: If they hit an island or something, the seeds, if they come flying out it's gonna land and nothing's gonna happen. They won't grow.

Ps: Oh, I know. I know.

information which the Ps do not have.

LL.20-42: F-c

T's explanation includes science information which accounts for holes being smaller than seeds. Not in Ps' experience.

Ps' answers appear to be search for acceptable answer expected by T.

T: You mean, if they grow under water? That's good thinking, Andrew. Michael?

Michael: Because if too many grow on the same spot they wouldn't get enough sunlight and everything like that so it's, so they spread out.

T: Exactly. The plant wants to make sure that all the seed that's produced, and there could be many, many seeds in there, don't all fall next to the parent plant because the seeds won't survive. There won't be enough sunlight or soil to go around. So the plant has the seeds grown in a little shell where the seeds can't get out until they've drifted, maybe miles, on an open stream or on a lake or many hundred feet in a large pond. And then the seed case or shell, begins to rot and fall apart and the seeds can drop down somewhere where there are no other plants to take up all the soil and all the water and sunlight. It's to make sure that the seed gets far enough away from the parent plant to survive, just like the coconut. The one that falls in the water has a much better chance of surviving, if he gets to land, than all the coconuts that are stuck at the bottom of those trees. Now, would you look at the rest of these seeds and see if you can come up with any other way besides water that plants use nature to help them spread around. The seeds are designed to use forces in nature to spread them around (Ps: Oh! Oh!) and you find a seed and tell me what kind of force it might use. Paula?

Paula: The dandelion.

T: OK. The dandelion near

LL.4-8

P's comment is same as given in Episode III, p.A45, LL.5-15.

LL.9-36: F-c

T's explanation is reasoned from information given about dispersal.

Formal explanation appears to be T's way of assuring that all Ps understand irrespective of their lack of experience.

LL.37-47: F-a

T refers Ps to illustrations so that certain clues are found.
Particular observations are expected.

the bottom (of the page). Now what force in nature do you suppose the dandelion uses to spread the seeds around?

Paula: The wind.

T: Of course the winds (T writes on board under previous notes: 2] wind.) Have you ever seen it happening Paula?

Paula: People blow them around.

T: Sure. People blow dandelions around. What happens when you blow on a dandelion?

P: ---- .

T: Yes. If you look carefully at a dandelion ball, one of those puff things. If you look carefully you'll see little hairs, and at the end of the hairs are little black dots. What would those little black things be? Little grains of pepper, almost. Sandy?

Sandy: Seeds.

T: They're the seeds. I tried to get some seeds to show you. I went around yesterday afternoon after school. I looked around, but I couldn't find any seeds right now. Why not? Why couldn't I find seeds to bring in? Allen.

Allen: Because they are using them right now, to grow.

T: That's right. The flowers at this point, in this season, which is what season Allen?

Allen: Spring.

T: It's spring. They are busy growing roots and stems and leaves. They haven't got flowers

LL.1-4: S-c

T's question requires information from P's own experience.

LL.5-13: S-c

P's answer is a description derived from personal experience.
T's questions refer to Ps' experiences.
No theoretical explanation given or expected.

LL.15-41: S-c

T's information refers to seeds familiar to Ps. T uses simple, descriptive language.
No scientific knowledge is introduced.
(Implication that Ps' own experiences are considered to be important.)

yet to make seeds. All the seeds from last year are in the ground and already growing. So it's kind of hard to find any to show you. But there is a plant you can see in a lot of gardens right now, that's beginning, that will have seeds soon. It's a very common plant that you see around. Yes?

P: Bulrush.

T: In those gardens?

P: No. It's ready. (Ps: Oh! Oh!)

T: The bulrushes are ready, yes. But there is a plant that's almost ready to start making us sneeze and so on.

P: Tulips.

T: The tulips haven't got seeds yet. This one's close to making seeds.

P: Dandelions.

T: Yes. If you look in those gardens you'll see dandelions beginning to sprout everywhere. And once they start they begin to reproduce very quickly and they change from the nice yellow flower into that round puffball thing and as Paula told us, when you blow on it, or the wind blows on it, the thing falls apart and you can see next to the drawing there's a little tiny fluffy thing with a seed hanging from it. How does the wind carry that? Andrew.

Andrew: It's light. It floats.

T: Yeah. What thing do men have or people use to help them float through the air?

LL.5-42: F-c

T requests certain information which he expects, irrespective of Ps' answers which make sense to Ps (LL.11-15).

(Implies that T expects acceptable answers based on his own understanding.)

LL.24-42

T's comment appears to be a return to information related to Ps' understanding and experience, but he continues to request certain information which fits his understanding.

Andrew: Feathers?

T: Feathers work the same way, almost. Sharon?

Sharon: Wings.

T: Wings, perhaps. Yes. Michael?

Michael: A parachute.

T: Like a parachute. Eventually the little seed is going to land. It is carried on the wind a long time. You can see the large top and little seed underneath. Like a man hanging from a parachute. Why would a dandelion make its seeds like that? What's the point? Julia?

Julia: Well. When the wind's ---- it might land ---- .

T: It'll definitely land, yes. Sure, and it'll carry it away from where? Where will it carry the seed away from? Joy.

Joy: From the other seeds.

T: From the other seeds and from the parent. Right. Allen?

Allen: But there's one problem ---- because it has no leaves. It has no stem sitting out there.

T: The seed doesn't. Not yet. When it lands. When it blows away and lands in a good spot.

Allen: I mean the dandelion. It's only a flower and a...

T: A stem. It's got leaves. It's got roots. It's got everything there.

Allen: Yeah, but I've never seen any leaves.

LL.1-9: F-c

T does not accept P's logical answer until the one he expects is provided (L.8).

(LL.1-25 is example of difficulty in distinguishing between observation and explanation.)

LL.14-25: F-c

T's question is a request for particular reason, not necessarily derived from observation of the illustration.
P's comment limited by T's expectations. Note T's subsequent question as a request for certain information (LL.20-22).

L.26-p.A62, L.6: F-a

P has difficulty relating T's information to what he knows about dandelions (L.33).

T refers P to illustration so that certain information is perceived by P, thereby confirming T's comment.

T: Oh, look at the dandelion closely. There's leaves even in my drawing. There's leaves down at the bottom. They're not at the top like our bean plants. They are down close to the ground. Can you see on here any other seeds that we spread around by wind?

Ps: Oh! Oh! Please Sir?

T: Karen?

Karen: The burr.

T: The burr. This one here or this one over here or the two? The little one? I don't think so.

Ps: No. I know! I know.

T: I said the wind. Think about it, Chris ---- can you see any others that might be carried around by the wind?

P: No.

Ps: Oh! Oh! Sir.

P: The milkweed.

T: Yes. You can see milkweed in late summer. I don't think you'll see milkweed before. Can you describe it, Andrew?

Andrew: It's like, well it's got a stem growing up -- .

T: Yeah. How tall would you say the stem was?

Andrew: I don't know. Tall.

T: Yeah. It's quite a tall plant.

Andrew: I squeezed it and all the milk -- .

P: Oh, those things.

LL.6-25: F-a

T refers Ps to illustration so that certain information is perceived. T has assured this by inserting appropriate clues (LL.6-8).

T expects a particular answer and he does not accept Ps' suggestions.

LL.14-25: F-a

Ps' observations are limited to confirm T's expectations.

L.25-p.A63, L.6: S-c

T requests a description. P's description is derived from own visual experiences.

T encourages P to provide more descriptions of what he knows.

T provides no science information.

T: Yes. If you break the stem it's got sort of a milky substance inside. What does the seed case look like?

P: A round thing?

P: It looks like a dandelion.

T: Not a milkweed. No. Inside it might. What does the milkweed seedcase look like, Michael?

Michael: There's something shaped, almost like a boat.

T: You mean like this, sort of? (T puts sketch on board.)

Ps: Yeah.

P: And inside, it's sort of like feathers, inside. It's not always at the top.

T: That's exactly it. If you see a milkweed plant, usually around August, there's at the top of the plant where the flower used to be, a case. A soft case that has become dry. That cracks open and what's inside, Michael?

Michael: Feathery things. On the end they're seeds.

T: Yes. Sort of light, fluffy material with seeds at the end. Can you see any others that are spread by the wind? Karen?

Karen: The other one.

T: Ah, no.

Ps: No. Mr. ---- oh!

T: Raise your hand. We'll get to you.

P: The bulrush.

LL.1-17: S-c

T solicits and accepts descriptions from Ps' own experiences.

No scientific information is provided.

T's comments refer to Ps' experiences.

LL.18-32: S-c

T does present some information which may not be familiar to some Ps, but T appears to give more importance to Ps' contributions than to his own (LL.28-30).

LL.34-p.A64, L.33

T appears to return to requiring certain information as the answers to his question (L.34), however this impression is not borne out.

T: The bulrush. Yes. What happens to a bulrush, James, when it's ready to spread seeds?

James: ----

T: Yes, I'm sure you've all blown on bulrushes. They've fallen apart.

Ps: There's one more.

T: Inside the bulrush are seeds again on little fluffy hairs that catch the wind and blow with it. Allen?

Allen: And the maple.

T: And the maple. Yes. How does the maple work? We've all seen those.

P: Helicopters.

T: Natasha? Look at the maple in the picture. How does it work, do you think? We've had parachutes so far. What else have we got here?

Natasha: Helicopters.

T: It works like a helicopter. Yes. You can see the two large wings and the seed down at the bottom. And how do they fly, James?

James: They spin.

T: Yes. They spin like this (T moves hand in spiral.) and in a strong wind they can stay up for quite a distance. Why did the plant design it's seeds with wings like helicopters, Andrew?

Andrew: Like when it ---- the seeds could go in different directions instead of ---- .

T: That's right. What's the

LL.5-33: S-c

T's comments and questions refer to Ps' experience with familiar seeds.

Although T refers to illustration (LL.19-20) his question requires an interpretation derived from Ps' experiences.

T presents no other science information.

L.33-p.A65, L.3: F-c

T requests an interpretation. P's answer not likely drawn from experience, but based on information given.

T expects Ps to use scientific term.

word we should be using all the time?

P: Dispersal.

T: Yes. It designs its seeds that way so that it can disperse the seeds over a large area to give them a chance to survive. Now would you just very quickly put a W beside the seeds we just talked about. The W standing for wind, or you could put the whole word wind if you wish, next to the seeds we discussed. These were the dandelion, the maple and the milkweed. Those are spread around by wind...

P: By grasshoppers.

P: And the lotus.

T: How is that spread around? And next to the lotus, put the whole word water.

P: What about the bulrush?

T: Next to the bulrush also. It's also spread around by the wind. Now there's a third way in which nature plans its plants so that seeds can be spread around and dispersed. Looking at the remaining seeds, ones we haven't talked about yet, see if you can figure out how they're spread around.

James: The burr sticks to dogs and everything.

T: What word can we use instead of dogs? What is it that does the dispersing?

Allen: Well when a person, like, grabs a cherry or something. They eat it and they keep the seed and they put it, you know, they throw it away and then it starts to grow.

LL.3-28: F-c

T's comments logically derived from information given in lesson.

Ps' comments derived from lesson, not from their own understanding or experience.

LL.28-34: F-a

T directs Ps' attention to illustrations. Certain information about dispersal should be perceived, which T expects.

T: Perfect. What do we call people, and dogs? Troy?

Troy: Humans?

T: Not dogs.

Ps: No. No.

P: Animals.

T: Yes, animals. The animals are one of the largest groups to help spread seeds around. (T writes animals on board under previously written water and wind as follows:)

1) water
2) wind
3) animals

Now, James told us about a dog walking through. What could be things besides mammals. James mentioned the burrs which have hooks on them which catch onto the fur or people's clothing. How many of you have had a burr stuck to your socks after you've climbed in the forest? (Ps laughing.) OK. You know what I mean. They are very hard to get out. So when you walk past a plant that has burrs, and then you might go on a long hike for two or three miles and then you'll pick the seeds off and you'll throw them away. Well those seeds have been dispersed by you, or by your dog when he comes home and you take the burrs off him. Now would you put an A next to burrs and stick-tights. That's another kind of seed that sticks to clothing or to animals' fur. There are two kinds of burrs. They both hold in the same way. Next to burrs and the stick-tight. Now what happens to the cherry? How do you suppose it's spread around? Water, wind,

LL.10-46: F-c

Recording of appropriate information may be the T's way of ensuring that all Ps have the scientific "rules" or information necessary for understanding seed dispersal.

Some reference is made to Ps' experiences, but way in which information is presented implies that is a confirmation of T's own understanding and what he expected the information to contain.

animals?

P: Animals.

T: How would the animals help to spread cherries around, wild cherries?

P: ---- .

T: As Allen told us if you pick a cherry off a tree, a choke cherry, or some kind of wild berry, and you eat it and you're going along chewing it and then a few hundred yards later you spit out the pit or the seed, you'll help that tree to spread its seeds around. Michael?

Michael: Or if you eat the whole seed, your body won't take the seeds and ah, whatever.

T: Yes. A strawberry. If I gave you this (holds up a strawberry) what would you do with it?

P: I'd eat it.

T: Yes. Would you pick out those little hard things inside?

Ps: No.

T: Luckily they don't bother us too much so we just swallow the whole thing. Now those seeds, it's not over for them. It's just beginning when you swallow it, or when animals take a bite of a strawberry. What happens to the seeds?

P: It comes out the other end.

T: Yes, as waste material. When you finish digesting strawberries, the good part, the juicy part stays with us, the seeds will pass out and the birds or an animal that's eating, a day later or so, the seeds will be dropped somewhere

LL.3-15: F-c

T requests an explanation. P's unheard comment might be a necessary clue to analysis.

Explanation presented by T appears to be a review of information given previously.

LL.16-41: F-c

T's extended explanation appears to include information from own understanding.

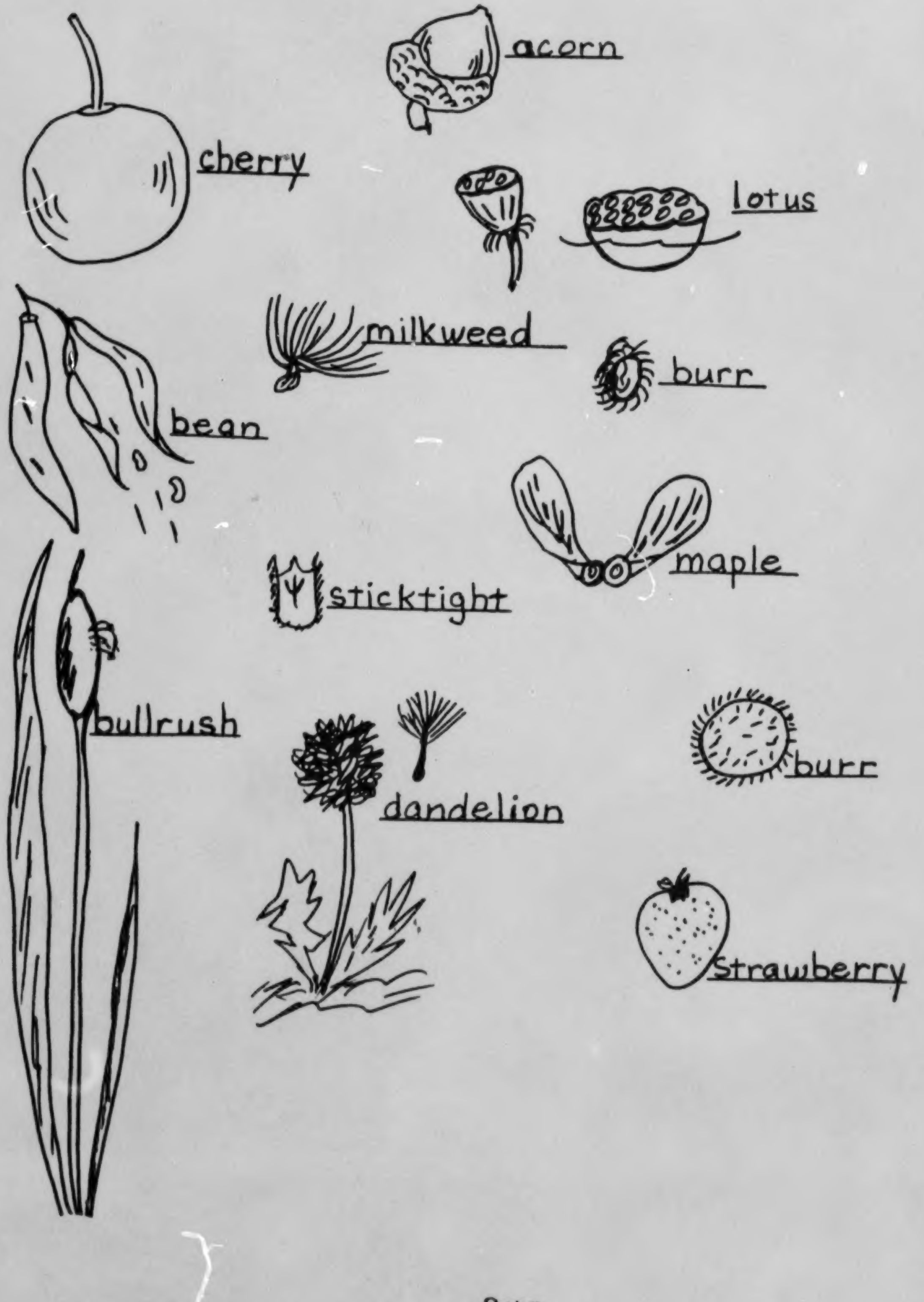
Ps are not expected to clarify their comments. Limited explanation confirms T's expectations.

else, and they'll be spread who knows how far from the parent plant. Later on today I'm going to pass this strawberry around, you have to go to French now, and I want you to see the top here under a magnifying glass. You see the sepals and you can also see the anthers that are shrivelled up and just left at the bottom. We'll have to do it today before it gets any mushier. Now would you please take out your French books.

Classroom Management

(End of lesson.)

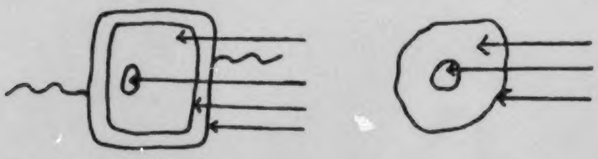
# Seeds


acorn
cherry
lotus
milkweed
burr
bean
maple
sticktight
bullrush
burr
dandelion
Strawberry

## SCIENCE LESSON - 04

## Examination of Cells

(26 Students enter classroom and are assigned to prearranged seats. The following drawings are on the chalkboard:)



(The lesson begins.)

Teacher: (T hands out micro-slide-viewers (1).) We're going to have the same problem as the last time. One for every 4 people. (T passes out work-sheet appended at the end of the transcript.) Don't work on the sheet that I gave you. That work-sheet, leave it alone for awhile.

(Ps sorting themselves in groups with 1 micro-slide-viewer per group. T sits on T's desk at front.)

Leave the microviewers on the side. OK, now let's get at it. What do we mean when we say that cells are the building blocks of all living things? Exactly what do we mean? Cells are the building blocks of all living things. Come on, I want to hear it loudly.

Pupil: Cells are the building blocks, means that your body is made out of cells and the body of animals is made out of cells.

T: Animals only?

P: And plants.

T: Plants as well? You mean--

L.2

(1) is the first of three numbered notes explained at the end of the lesson, p.A90.

Episode I

(L.17 - p.A74, L.4)

LL.17-31: F-c

T's question requests certain science information, not a description of events observed.

P's answer is not a result of observation. Suggests science information given previously. Confirms T's expectations.

T continues to structure questions so that certain information is given.

1 P: All living things.

T: All living things. How small are they or how big are these cells? Can you see them?
5 Can you look at them?

P: No.

T: You can't see them? How do you know that they're there? How do you know they're there?

10 P: You can magnify them.

T: You can magnify them? OK. Are all these cells alike? Are all these cells alike?

P: No.

15 T: They're not alike. They're different. Pardon me?

P: The yolk of an egg is one cell.

T: Many cells. Are all cells
20 alike? All the cells that you saw, are they all alike?

Ps: No. No.

T: Well explain something. How do some of them look like?

25 P: ----

T: ---- different types?

P: Yeah.

T: And didn't some of you remark, "Look at this funny one!"

30 P: Oh, the nerve cell.

T: The nerve cell. How did the nerve cell look like?

P: Well -- its sort of like, ah, like a rake on one side.

LL.2-4: F-c

T's question requires certain science information.

LL.7-11: F-a

T's question can be answered from experience with viewers. The Ps saw the cells and were told that they are magnified.

LL.12-21: S-a

T solicits information from Ps' personal observations. Answers depend on Ps' perception of cells.

L.24-p.A72, L.32: S-a

T solicits descriptive information derived from Ps' own observations.

T does not clarify Ps' observations.

T: Looks like a rake? OK. What else?

P: The muscle cells are long and thin.

T: The muscle cells looked long and skinny. OK. Go on. The muscle cell looked long and skinny.

P: The skin cell was roundish.

T: The skin cells looked roundish. Yes. OK. More.

P: The onion cell ----

T: Oh yeah. The onion cell was more square.

P: Rectangular.

T: Rectangular. That's right. Rectangular. Others? Which one was it that I told you that no one would get?

P: The muscle cells?

T: Muscle cells? No. Everyone got that. Everyone could tell me they knew it was muscle cells.

P: Nerve cells?

T: Nerve cells. Remember they were just ----. We also saw bone cells. Cells of bone. Remember that? OK. We also saw cells from leaves, cells from the onion, cells from a woody stem. Remember those?

P: Cheek cells.

T: Cheek cells. Right. OK. They weren't all the same. It depends of course. What does it depend on, how the cell looks like? What does it depend on for how it does look like?

T and Ps talk about observations using descriptions.

Implication that viewer enhances visual acuity so that Ps' observations are (scientifically) acceptable.

LL.1-35: S-a

Ps use descriptive language. T does not alter Ps' descriptions. He accepts their perceptions.

LL.21-33: S-a

Ps' observations expected to enable Ps to recognize type of cell perceived.

L.36-p.A73, L.16: S-a

Question appears to be request for explanation but T refers to appearance.

P: There's certain things ----

T: You mean different cells from different parts, let's say of our body, right?

P: Yes ----...

T: So if something - he's right, if something, we need a cell, the types of cells we have are from the different functions of our body. ---- Remember the two types of muscle cells? One was from the arm or leg and the other was from the stomach. Everyone could tell it was a muscle cell because you said it was long and thin. Right? OK. Now is the muscle cell going to be the same as the cell that's going to be found in your bones?

P: No.

T: Everyone's nodding his head. But no one seems to want to reply.

P: Sir.

T: We just said that everything was made out of cells, right? OK. Everything is made up of --. Is there anything that is made up of one cell? Can you think of anything that's made up of only one cell? Or does any such living thing exist? Made up only of one cell. (Ps hands up.)

P: Amoeba?

T: The Amoeba. That's good. What other? You even looked at it. It had to be magnified many, many times, 1200x. What am I thinking of? They were round. Some were not round. Others were long, sausage shaped. (Ps hands up.) They were #8 (referring to slide number). Remember? Only three of you

Implication that observation of cells generates an understanding of their function.

LL.6-21: S-a

T's comment supports implication above. Function of cell can be understood because of Ps' observations.

LL.29-31: F-a

T's question does not appear to depend on observation. Nor does it request an account of a single-celled living thing.

Ps expected to recall certain observations made in previous lesson. Answer expected to confirm T's preconceptions -- what he is thinking of (LL. 39-40).

T's expectation is more important than P's answer (L.35).

remember. Very, very tiny. Very important.

P: Bacteria.

T: Bacteria. Now, the person with the microviewer come up and get 1 slide. Don't put it in yet. One of number 11 and wait, because you're going to get number 10 as well (2). (Ps at front collecting microviewer slides.) Will you come back to get the other one too please. One more. OK, everyone's got one. Now, you're going to be working again in groups of 4. OK? Insert in the slit, the number 11 is it? The cells of plants and turn it to #1, put it to #1 (3). OK. That's your onion cell. Right? (Students looking through viewers.) I want you to first have a look at the onion cell. Everyone. OK? Once you see it, pass it on to your neighbour and we're gonna work on these sheets (refers to worksheet with drawings of 2 cells). Now look at the boundary of the onion cell. By boundary I mean each cell is pretty well defined. Right? Having a boundary. Just the plant cells right now.

P: Which one is that?

T: That's number, um, number 11. Isn't it? Yeah number 11, the #1. Look at the boundary of the cell. That's all you're focusing on. You'll have another chance.

P: We saw this.

T: Yes, I know you have, but I want you to have a look at the boundary of it. Is there one boundary or two in each cell?

P: (quietly) What's those things?

LL.1-4: F-a

P's answer confirms T's expectations and is accepted.

LL.5-17

Classroom Management

Episode II: F-a

(L.19 - p.A78, L.9)

LL.29-44: F-a

T structures Ps' observations. Indicates what they are to look at.

1 P: One.

T: Is there one boundary or two
boundaries in each cell? Does it
have two boundaries or is it one
5 big thick boundary? Have a good
look. Two boundaries?

P: I didn't see it.

T: You didn't see it. Ah!

P: Two.

10 T: Two. You're sure. (P: Yes)
Take another look. Everybody have
another look. You think two is
right eh? Two?

P: One.

15 T: One? Take another look at it.

P: Two.

T: Two. How about you guys at the
back? One or two boundaries? Two?
Yes, there are two boundaries. Even
20 my drawing, on the sheet and on the
board has it. OK? Now the outside
boundary of each cell, OK. In my
drawing these (points to wavy line
at side of cell) are indicating
25 other cells are right beside it,
because the onion, as you see it,
it's like a bunch of bricks laid
one on top of the other.

P: ----

30 T: Oh, that's right. Magnified
110x times. Put it underneath
your drawing and write in the
name onion skin, right under-
neath. (T writes ONIONSKIN
35 CELL under chalkboard drawing
and writes 110x under label.)
And don't forget, this (points
to 110x) means 110 times.
OK. That means that the onion
40 skin has been magnified 110
times for you to see it. And
yes, it's true, it has two boun-

LL.1-17: F-a

T structures Ps' observations so they perceive certain structures. Ps' observations may be altered to confirm what is expected (LL.7,9,14).

LL.9-15: F-a

T expectations are apparently more important than Ps' own perceptions.

L.15. Ps' answer expected to confirm T's understanding.

LL.17-21: F-a

T ensures that Ps will make appropriate observations by providing the slides and drawings showing two "boundaries".

LL.41-p.A76, L.1: F-a

T confirms "correct" answer.

daries. OK. The outside boundary — Does anybody think they know the name of the outside boundary? What do you think they would call it? Does anyone want to take a guess?

P: Membrane?

T: Membrane? No.

P: Well, what is a boundary?

T: Well that divides one cell from the other. OK? What you're seeing is a number of cells put together. Can you see that? You saw them?

P: Yeah.

T: Right? One close to the other. We are only looking at one. We're only choosing one. There's two boundaries. That is, each cell seems to have 2 boundaries. OK. The outside boundary is very simple. It's called the cell --

P: Boundary.

P: Wall.

T: Cell wall. Good. (T writes cell wall on appropriate line of chalkboard drawing.) Who was that? (P's hand up) That's great. Now, what do they call the inside boundary? You said it.

P: The membrane?

T: The cell membrane.

P: Sir, do we ----

T: Yeah, write it in. (T writes cell membrane at appropriate line of chalkboard drawing.) OK? When you are finished have another look at your cell. One more time.

LL.1-6: F-a

Ps expected to use appropriate science terms (labels) when referring to observations.

LL.9-21: F-a

P does not understand meaning of term in context of question or P's own observation.

LL.11-22: F-a

T directs Ps to observe particular structure. No explanation involved.

LL.22-36: F-a

T expects particular scientific term which he considers more acceptable than simple label.

Ps expected to use correct terms.

Another look at the cell. Now have a look at the cell inside. This part here. (T points to part of drawing inside membrane.) Have a look at this part of the cell. The inside of it. You can't really tell, on a slide like that, but that's made of a liquid. I don't think anybody knows the name of this. You think you know? No, not there, the inside. Is everyone looking at that? All of this material inside of the cell is called the cytoplasm. (T writes cytoplasm on board on appropriate line of the drawing.) Cytoplasm. Has anybody ever heard of that?

P: No.

T: No? Okay. (Ps writing, labeling drawings on work-sheet.) In fact when we did look at it, you were telling me, "What's all those letters inside?" Well, there you are. Now notice how it's spelled. Cy-to, Cyto. OK? Cytoplasm.

Ps: Cytoplasm.

T: And that's all the material made up inside the cell. Now that leaves us with one more little structure to look at and that's that little round (Ps hands up. Oh! Oh!) ---- inside that either looks like a bean, more or less looks like a -- What do we call it?

P: Nucleus.

T: Nucleus. Yes (T writes it on the board beside the drawing.) Remember last -- Was it last week that when we looked at the cells, you asked me about that structure and you said that it was found in all cells, all the cells you've looked at?

LL.1-13: F-a

T directs Ps' observations so that certain structures are seen.

LL.6-9

T realizes limitations of slides for viewing particular structure. He expects Ps to perceive certain material and he provides scientific term.

LL.17-20: F-a

Use of term expected even though there is no link between Ps' limited perception and understanding of term.

LL.30-46: F-a

T directs Ps to particular structure and provides clue to recognition.

Ps use appropriate label.

P: Yes.

T: OK. Keep that question in mind. Everyone see that little structure inside? Everyone look at it.

P: What's that line?

T: Which one? This one? (Points to ∿∿ line at side of drawing.) That means another cell is there. Now turn to number 10. Slide number 10 and look at #1.

(Ps using viewers. Take turns looking at slide.)

P: We looked at these.

T: Yeah. We looked at those too. But did you know what they were called? What the structures were called? The last time we looked at them, the onion and which is this one again? Does anyone know?

P: The skin cell.

P: The cheek cell.

T: The cheek cell. Right. (T writes CHEEK CELL under drawing.)

P: How much is it magnified?

T: It's magnified -- let me find out. (T opens slide holder information card.) 900x. Magnified 900 times. So when you look at these two (points to 2 board drawings) OK, you see that the onion skin cell is much larger than the cheek cell. Did I tell you how they got that slide?

P: No.

T: Well simply by -- yes I did.

LL.2-5: F-a

Ps expected to perceive certain structure.

Episode III: F-a

(L.11 - P.A79, L.29)

LL.15-25: F-a

Ps expected to use scientific term when referring to observations made.

LL.23-25: F-a

T expects Ps to use certain vocabulary even though P's answer is appropriate and understood by P.

LL.27-35: F-a

T does not explain about magnification in this lesson. T directs Ps to notice difference in size.

P: They use a red dye. (Ps hands up. Oh! Oh!)

T: No. Yes, they do put red dye. You put a toothpick in your mouth -- yeah?

P: And scrape some off.

T: That's right and scrape some and some cells are gonna come off and you put them on your slide and add some red dye. That's why they are red, because of the red dye. OK? Now do you see a nucleus in that one?

P: Yeah.

T: The same thing as this one.

P: Yeah.

T: Alright. Everyone could see that one. (T writes word nucleus on appropriate line of drawing.) Let me ask you a question. Do all cells have a nucleus?

P: Yes.

Ps: No. No way.

T: Why no? Why yes? Do all cells have a nucleus?

Ps: Yes.

T: Do plant and animals cells have a nucleus?

Ps: Yes.

T: Turn to the next slide. #2. Those are blood cells. #2.

P: They have nucleuses.

T: Take a look at them.

P: They don't have a nucleus.

T: Take a good look. Will you

LL.12-18: F-a

Ps' observation limited to and confirm T's expectations. T directs Ps to particular structure.

LL.20-25: F-c

T's question is request for science information based on knowledge about cell structure, which Ps do not have. Answer cannot be derived from observation of few slides. Ps appear to be searching for appropriate answer.

LL.27-28: F-a

T's question not a request for explanation. Refers to certain information derived from observation.

Episode IV: F-a

(L.30 - p.A82, L.5)

LL.32-35: F-a

Ps alter their observation to confirm T's expectations, irrespective of own perceptions.

do that please? Back there. Take a good look.

P: I can't. I haven't got the viewer.

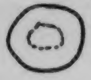
T: Well, you wait. Now can you find the nucleus in the blood cells?

Ps: Yeah. Yes.

T: Where did you find the nucleus? The white stuff?

Ps: Yes.

T: Ah. No. Actually the cell looks like a donut. Doesn't it? It looks like this. (T draws on board.)



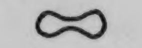
P: Red dye.

Ps: Yeah.

T: Just a minute. Look, it's round. And in the center...

Ps: Yeah it's got white. It's all white.

T: It's coloured more -- well in the center it seems all white. You know why? Because if you took that little cell and it was possible to just turn it. OK. You find that it looks something like this. (T draws on board.)



P: So how come we don't see that?

T: Well because it's not turned. You're looking at it from the top. You're standing and looking -- well if I were to look at this garbage can on top, (T looks down into wastepaper container.) I would only see something round. I could

L.35, p.A79-L.2

Impression conveyed in that a good look can reveal important information. (undercurrent of S ideas)
but

LL.5-13: F-a

Ps' observations are limited to T's expectations irrespective of Ps' perceptions.

LL.12-28: F-a

T expects Ps' observations to confirm his understanding.

LL.22-28

T refers to what Ps "see" and he describes what they should see. (Not an explanation. Reference is to observation.)

L.29: F-a

Evidence of Ps' confusion between value of their observations (S) and their inability to perceive what the T expects them to see (F).

never tell if it was like this. (T holds up can.) That's why it's difficult.

P: Why?

T: Because you're only looking at ---- you're not looking at three dimensions. OK? That's why those cells that you're seeing ---- no they don't have a nucleus. (Ps noisy) Give everyone a chance to see please. OK? No, you may have, but in the back they haven't finished. OK? (Ps examining slide, talking and laughing. T circulating.) Will you give that back, over there, please? Just give that back. OK? Do all the cells have a nucleus?

LL.5-10: F-a

Ps' observations expected to confirm T's understanding irrespective of their perceptions.

LL.18-23: F-c

T's questions require certain science information. Ps do not understand what T expects.

Ps: No! (chorus)

T: Give me an example of one cell that doesn't?

P: Onion.

T: Blood cells.

P: My mother used to work in a lab ---- with white blood cells.

T: Uh huh. What are white blood cells? What do they do?

LL.26-27: F-c

T's question requires science information which Ps do not have.

P: Kill ---- (laughing).

T: What was that? What do they do? Someone may know something.

P: Oh! Oh! I know.

P: They fight off germs.

T: That's right. That's it. What do they call the material inside the cell? Everyone have a look at that and tell me, what do you think they call it?

LL.33-38: F-a

Ps expected to use certain terms for the material observed.

P: Cytoplasm.

T: Cytoplasm. (Writes cytoplasm on board.) Have a good look at that again. At the cell. Have a good look at it. (T waits at front desk.)

P: ----

T: Today you're on cell #1.

P: One?

T: That's right. Cell #1. The cheek cell.

P: Cell #1 is the onion cell.

T: Yeah, but it's cell #1 still. We're on a different slide. There's cell #1 for number 10 and cell #1 for number 11. The cheek cell is magnified 900x. You didn't put it on? Add it onto your sheet. (To a noisy pupil) I realize that it becomes quite difficult waiting for someone to finish but if someone is looking at that, the rest of you are to keep quiet. Now check to see the boundary of the cell again. The boundary of the cell. The cheek cell. We're still on that one. Cell #1. Check the boundary and tell me, what do you think they call it?

P: Cell wall?

T: Cell wall?

P: Cell wall.

T: Cell wall. Anybody else?

P: Cell wall.

T: Cell wall. Are there two boundaries or is there only one in that one? (Ps hands up)

P: One.

T: One only. It's called the cell membrane. (T writes membrane

LL.1-4

Undercurrent of sensationalist ideas. (Implies that a good look should enable Ps to perceive and recognize cytoplasm.)

LL.7-26

Classroom Management

Episode V: F-a

(L.26 - p.A86, L.4)

LL.26-39: F-a

Ps expected to use scientific terms for particular structures observed. Ps uncertain of T's expectations.

T expects Ps' observations to confirm what he knows.

on appropriate line of diagram.)

P: Cell membrane.

P: Membrane.

P: Cell membrane.

P: It looks like more.

T: What you're seeing is two cells. That's why. You're seeing two of them. Now below those two is a question. (T refers to work-sheet.) Below the two drawings. OK? From what you have seen, explain the difference between an animal cell and a plant cell. Write it down. Write it. (T repeats question and circulates.) Here I'll give you this sheet (to one P) and what you'll do is when you have time put the information on it. OK? There's the question. What's the difference between the plant and animal cell? You can see that. Can you not? (To one of Ps) What's the difference between this (points to one drawing) and this? (T points to other drawing on work-sheet.)

P: (Looks up at chalkboard.)

T: No. No. Look at them! Look at them. You've got your microviewer. Look at them again. (To one of Ps) You can't figure out what the difference is?

P: ----

T: Can't you figure it out? Well look at them. It's right there. It's easy.

P: Oh yeah.

T: (T circulates, talking to Ps.) Well find it. You can. You know what it is. Look at the boundaries. You have names

LL.5-8: F-a

Ps' observations expected to confirm T's understanding irrespective of Ps' own perceptions (1.5).

LL.12-26: F-a

An account of cells is not expected, a description is required based on Ps' observations of slides and diagrams.
Ps' observations are limited to T's expectations.

LL.21-22

Ps expected to perceive the differences considered to be important.

LL.28-42: F-a

Undercurrent of sensationalist ideas. Value of observation in recognizing "difference" implied. However, T expects Ps to make particular observations and thus note certain differences (LL.41-42).

for them.

P: ---- the shape.

T: I don't think it's the shape.

P: Well it is -- ...

T: OK, if you want to. But you've only got two cells. But have you never seen a cell from a plant look roundish? Yes we did. (To another P) No, don't say anything. Everybody has to discover it on their own.

P: I don't think it's the shape.

T: Well what do you think? Yeah, well OK. Partly that's it. It's pretty specific. You can see it. Take a good look at them. That's what I said. (To one P) OK, there you are. The membrane's there and the cell wall, there. Come on. Settle down. Settle down. I'm getting people telling me that one is round and the other is rectangular. True. Alright. What is the difference?

Ps: Oh! Oh! I know. I know. Sir.

T: Put your hand up. What is the difference? Yeah?

P: Because the animal cell has only a membrane but a plant cell has a wall too.

T: Sure, the plant cell has a cell wall and a membrane. An animal cell has only a cell wall. OK?

P: Only a membrane.

T: No. I'm sorry. Do I have this wrong? You're right.

P: Animal cell has only a

LL.2-9: F-a

Ps' observation must confirm T's expectations.

L.12. P changes answer since it does not confirm T's expectations.

LL.16-25: F-a

T expects a particular answer based on observations. T structures observation so that certain characteristics are evident.
(Implication that Ps' perceptions are not as important as T's understanding)

LL.30-36: F-a

P's answer confirms T's expectations and is derived from P's observation.

membrane.

T: One more time. The plant cell has a membrane and a cell wall. The animal cell has only a membrane. Is that what I said, or did I say the opposite?

Ps: Yeah. You said the opposite.

T: OK. One more time. Plant cell, like our onion cell, has a membrane on the inside, a cell wall on the outside. Two boundaries. OK? While the cheek cell has only a membrane. No cell wall. Animal cells do not have cell walls. And you can go through, now that you know, look through slide number 10 and you will not find any one of those cells with a cell wall because they're animal cells, from the human body. OK? When I was looking around, a lot of you said that one is rectangular, the other one is roundish. OK. Any questions? About what we did.

P: ----

T: Louder, louder. (To other Ps) Someone is trying to talk.

P: The last ones of the plants, is it bacteria?

T: The last ones of the plants. I don't have the plants (refers to slide set), you have the plants. The last one, #8?

P: Yeah.

T: Yup.

P: Does it have a cell wall and membrane?

T: Yeah. Sure. Because -- Yeah those bacteria that you have they are magnified 800x. OK? Now. Oh,

LL.2-16: F-a

T repeats acceptable observation. No theoretical account given.

LL.16-22: F-a

Evidence of T's provision of certain slides so that expected observations would be made by Ps.

LL.38-42: F-c (?)

P's question is a request for information not derived from observations. T alters own answer, suggests limited knowledge.

we didn't give out the books. Give him a hand. The rest of you take this sheet, and make sure that by next week it's in your notebook. Either staple it in your notebook or glue it in. (Ps handing out textbook: Rockcastle et al., STEM science, 1977. T calls in the microviewer slides. Ps bring them to front, and place the microviewers on the window-ledge.)

LL.1-15

Classroom Management

T: OK. Sit down now. Let's go. Hurry up. (T sits at desk in front of class.) Come to think of it, you asked me to question about bacteria having a cell wall. I don't think so. 'Cause they exist alone don't they? They don't need a cell wall. To understand the cell of a plant (T comes forward and shuts a P's book), take an egg. Alright. An egg is a perfect way to describe the cell and look at it on page 94. Can you see how? What would the hard part of the egg be?

Episode VI

(L.27 - p.A88, L.39)

L.27-p.A87, L.31: F-a

T focuses on scientific terms for structures found in egg.
(Incorrect analogy not the issue for this analysis.)

P: The membrane.

T: The hard part of the egg.

P: Oh, the cell wall.

T: The cell wall. On the inside of the egg is --. Have you ever seen it when you peel it? Yeah, there is a membrane. Right. Thin. It's the cell wall that's the hard part. Right? And in the inside you have your white of the egg would be your --

P: Cytoplasm.

T: Cytoplasm. And your yolk would be --

P: The nucleus.

T: The nucleus. OK? It's a perfect way to visualize a cell. Think of the egg every time I ever ask you the make-up of a cell. Your outside part -- no I want him to answer. Your outside part would be your what?

P: ----

T: I'm glad you're listening.

P: Membrane?

T: Good. I'm glad you've been listening too, all the way through.

P: The cell wall.

T: Your cell wall. The inside of it, between the yolk and the cell wall is a thin, thin layer. We're going over the same thing.

P: Between the white and the membrane.

T: Between the ---- I'm sorry what did I say?

P: You said between the yolk.

T: No, the white and the hard part -- It's your --

P: Membrane.

T: Membrane. And then on the inside it's your white of the egg and that would be your cytoplasm. Your yolk would be your --

P: Nucleus.

T: Nucleus. OK. Now, then it's the cell walls that are responsible. Look at -- let's read that paragraph. Cell walls. Loudly. (Ps hands up)

P: (Reads from textbook.) "Many plants have stiff walls outside their membranes. Some

LL.1-31: F-a

T focuses on recognition of certain structures and use of scientific terms to label those structures.

have stiffer walls than others. The cell walls..." (Rockcastle et al., 1977, p. 94).

T: Wait. Let me ask you a question. Why would some have stiffer walls than others? Give me an example. The leaf of the plant has cells. The cells from the leaf also have cell walls. Right, Sasha? Do they?

LL.4-25: F-c

T structures questions so that certain information is provided which T expects.

Sasha: Yeah.

T: OK. The leaf bends. Right?

P: Yeah.

T: The cells from the stem, if it's a woody stem, have cell walls too. Right?

P: Yeah.

T: When you bend a woody stem, what happens to it?

P: It bends.

P: It breaks.

T: It breaks. Which would have harder or stiffer cell walls? The ones from the leaf or the ones from the stem?

P: Stem.

T: The stem. Go on.

P: (P resumes reading from text.) "The cell walls in wood, for example, are thicker and stiffer than cells in the leaf. There are no walls." (Rockcastle, 1977, p. 94) (P completes reading the section on page 95.)

T: So you're now beginning to see what the difference is. Right? Everybody? So the cell wall is the basic difference between a plant and an animal

LL.35-p.A89, L.1: F-c

T's information derived from own understanding and textbook.

cell. Everyone? Now next week we're gonna go on. I'm going to spend all the time on cells. Next week we'll talk a little bit more about cells but eventually we're going to get to the different organs. Now, what is an organ?

L.4-p.A90, end: F-c

T uses structured set of questions to derive certain information.

P: Something that makes your body grow.

T: Something that makes your body grow. Give me an example of that.

P: Eyes.

T: Eyes. Another one.

P: Heart.

T: Heart. Good. Another one.

P: The nervous system.

T: Well that's the whole system. I want an organ.

P: Ears.

T: Ears. OK. Another organ. Come on. You don't even know your own body.

P: Lungs.

T: Lungs.

P: Nose.

T: Nose.

P: Stomach.

P: Mouth.

T: OK. What are these organs made of?

Ps: Cells.

T: Each type of cell that makes

up a certain organ is going to be all the same?

Ps: No.

T: Would the same cells that make up your stomach, which is an organ, are they the same cells that are going to make up your heart?

LL.4-25: F-c

T's explanation is a review of information derived from his own knowledge, not from Ps' experiences.

Ps: No.

T: Everybody's saying no, but nobody's putting up their hand.

P: I already put up my hand.

P: The different kinds of cells have different purposes.

T: Different purposes. That's it. OK. In other words your stomach is needed for a certain purpose, so the cells that are going to make up your stomach are going to have to work a certain way? Your muscles are needed for a certain purpose. So the cells that make up your muscles are gonna have to be shaped a certain way and are gonna have to fit a certain function.

(End of lesson)

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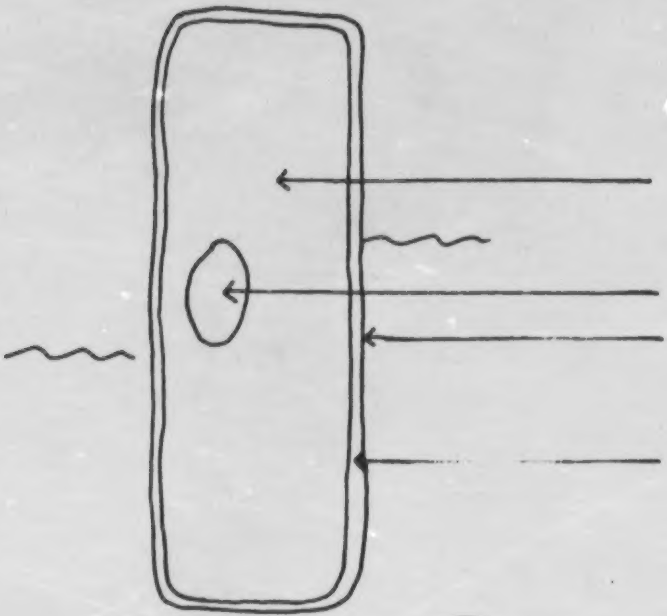
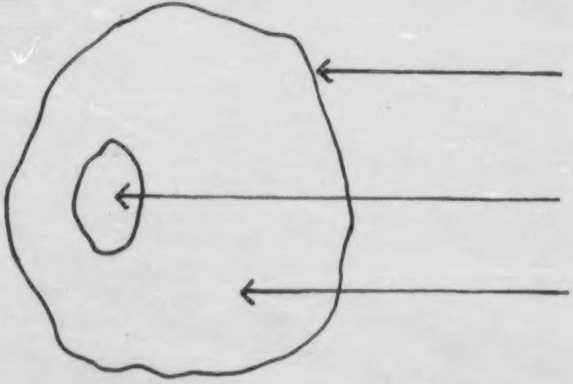
(1) Micro-slide-viewer (National Teaching Aids, Inc., N.Y.) is used to focus on magnified, transparent photographs of slides.

(2) Number 10 refers to slide set entitled Cells of Your Body. Number 11 refers to slide set entitled Cells of Plants.

(3) #1 refers to the first photograph of the slide set.

# Science





(1) From what you have seen explain the difference between an animal cell and a plant cell.

## SCIENCE LESSON - 06

## Batteries and Bulbs

(The lesson begins.)

Teacher: Albert, close the door please. Sh! Okay. Now, the bulbs - one per student only. We have a lot of work to do. (Ps instructed to hand out equipment to each member of a group. Ps working in 6 groups of 4.) Check to see if they are white, or PB or BW. Would you please take out your light meter that you have made. Yes, the bulb holders, also the elastics. I want you all to make a bulb holder. The fahnestock clips here, to each. That's okay, don't worry about that one bit. Everybody make a battery holder. You all remember how, I hope. We're going to continue where we left off last week. If you feel your bulb is not good try your neighbour's place, okay? And if you feel that your bulb is not lighting, then exchange with a neighbour. Do not use the copper wire. Be sure you use the covered wire.

L.1-p.A93, L.32

Classroom Management
Distribution of Equipment

(Material given to each P includes 1 battery, 1 bulb, a bulb holder, few fahnestock clips, 1 piece of insulated wire, 2 pieces of uncovered copper wire, and an elastic band. Each P has his own paper light meter. Ps working as material is distributed.)

LL.34-40

(List of Equipment)

T: (To one of the Ps)

Could you leave the bulbs over here please so that we can have them pick up their own? Where are the bulbs? The covered wire? Over there. If it is too big, double it. This is no good? Are you positive? You tried it? (T refers to bulb P brought to desk.) Okay, if it's absolutely no good, we'll discard it right away. Here, try another one. Yes?

P: There's something wrong with my light bulb. (T hands P a new bulb.)

T: There are a couple of elastics here. This one is better? Here, try this. Now, if you need the cutters, I'll put them on my desk. So the strippers are here. That's okay, don't worry about that. Now get organized. Make sure you get -- your bulb lights, but don't leave it on. We have to be a little bit frugal here. No Patrick, no. Use the strippers, here. Now last week, what we did, we connected our battery and what did we do with it? Do you remember, Sandra?

<ins>Episode I</ins>:

(L.33 - p.A97, L.5)

LL.33-p.A94, L.7: <ins>S-b</ins>

Ps and T talk about investigations carried out during previous lesson.

Use descriptive, non-scientific language based on sensory information.

Sandra: Miss, we took our light meter and we looked on what number it stopped.

T: Okay. How did you make your light meter?

Sandra: We took, for the first one, for number 1 we took...

T: What did you use to make it with?

Sandra: Paper.

P: 10 strips of paper. Like this strip of -- like an inch of -- I don't know.

T: Centimeters, not inches, okay?

P: Yeah.

T: Alright, and we made it with that and what did that light meter do for us? Claudia.

Claudia: It showed us, like, every paper we add on it gets thicker and thicker and we go on starting with 10, 9, 8, 7, 6, 5, 4, 3, 2, 1. We seen which number we couldn't see our light any more.

T: What did we try? What did we try it on? Who remembers? Did we try it just with that? What did we use? Okay.

P: Miss, we took our fahnestock clips and we made our battery holder and we placed it and then we took our paper and we went over it to see how high it was.

T: I know, but what did we use?

P: Miss, our fahnestock clips, a bulb, the bulb holder, the battery and elastics and wires and that's all.

T: And your bulb. But what were we testing with that?

LL.7-20: S-c

T's question appears to request explanation.

P's answer is a description of what was obvious and has been experienced.

LL.21-42: S-b

T continues to request description of Ps' previous test procedure.

Ps talk about test procedure using simple descriptions.

L.41-p.A95, L.6: S-c

P: Our PB bulb and our BW bulb.

T: Two kinds of bulbs. Do you remember? What's the difference between the two kinds of bulbs that we used? Okay, Richard.

Ps: Oh, Miss, Miss (hands up).

Richard: The PB bulb lights with a shine more brightly than the BW bulb.

T: We found that out. And how did we know the difference? There's nothing written on the bulb, but how do we know which one's which?

P: Miss, in the PB bulb the little thing is transparent and the WB bulb the little thing inside is pink.

T: What do we call that little thing inside?

Ps: Oh, Miss.

T: What's the word? I'm always trying to get you to spell that word.

P: A filament.

T: No.

P: A bead, a bead.

T: A bead, but another word for the bead.

P: A glass separator.

T: What's the word?

P: A glass separator.

T: Separator. That's the word and the word is

LL.4-17: S-c

T's question appears to be request for an explanation based on Ps' own experience (LL.13-17).

Ps provide sense-data descriptions of what is concrete and has been experienced.

LL.13-21: S-c

T repeats request for an explanation.

P uses sense-data description.

L.22-p.A96, L.3: p-M-c

T expects Ps to use appropriate scientific term for "bead" and she relates term "separator" to light intensity (which the Ps have been discussing) and with the word "separate" which the Ps appear to understand in the context of other school work.

There is insufficient evidence to indicate whether (or not) the Ps are aware of the link between the term "glass separator" and the function in a light bulb.

separate. I'm always trying to get you to spell that word. Okay. So today, we're going to do some testing, but not right away. What else did we make? Alright we tested that last week, but we made something else. We worked in groups. Who remembers what we did? Remember when we were working in groups and today we have to work in groups again and you should remember because you recorded it. I don't know - did you record it last week?

Ps: Yes, Miss. Yes, Miss.

P: Last week?

P: No, the week before. When we had two bulbs, two batteries and we put them together with the elastic with the ah --.

T: Alright, fine. Peter?

Peter: We used one or two batteries and we took our fahnestock clips and we made a series of battery holders and to see if the bulbs could light if they were connected altogether.

T: No. We only saw if they would all light. Did we check to see how bright it was, each one?

Ps: Yes.

T: Some did, maybe, but not everybody. And what did we call this?

Ps: A simple circuit.

LL.4-19

Classroom Management

L.32-p.A97, L.9: p-M-c

P attempts to explain purpose of activity (LL.32-34).

He makes sense out of activity by drawing on prior experience and understanding of circuits.

Ps' use of scientific terms show they understand the context in which terms are used.

T's correction also assumes Ps understand activity.

T: A simple circuit. And it is in a --

Ps: (in chorus) series.

T: Series. Okay. So we have that much done. We were at simple circuit in a series, and -- okay. Make a simple circuit now, again, and try your light meter. Try to see if the light -- if there is a difference from the bulb -- no, no. First of all -- you're not listening -- first of all, get together and form, like you did the other day, a series. Okay? Get together and form a series. Over there, you have a series of four. There, you have a series of four (points to groups of 4 students). Connect your four together and make sure your lights are all in a series. Now, what we want to find out today is the light, okay, the intensity of light. See if they all light the same. See if there's a difference. You'll find out why there is a difference, if there is. (T circulates from one group to the other.) Is the light the same for each one? Connect these together, all together. Make a series. (To one group) No, we did that. Do this, a series. How are you gonna work it? (Ps working. T circulating.) Did we do that last week?

Ps: Yes, Miss.

T: (To a group) No, no. Try it just with one battery, just to start. Maybe two, the most. One battery

Episode II: p-M-b

(L.7 - p.A103, L.24)

L.7-41: p-M-b

T's instructions or set avoids aimless activity by Ps.

T directs Ps' attention to kind of circuit to establish without telling them how to do it.

LL.25-36

T reminds Ps of purpose of inquiry without telling them how to carry it out.

She directs them to relevant clue (LL.28-30).

Use of scientific term "intensity" assumes that Ps understand meaning and context in which term is used.

LL.38-40

T continues to establish the parameters of the investigation. No information about procedure is given. T relies on Ps' prior experiences with and understanding of series circuits.

or two only, okay? (To a group) Well, one battery or two. Try it with one.

(Microphone taken to Group 1 of 4 girls)

P1: We have to connect -- wait.

P2: You connect them all together.

P1: Okay.

P2: There's no battery on this.

P1: Okay. Wait! There's no bulb.

P3: Okay, go get the clippers over there.

P2: Okay, cut it there. Okay, about there. (P tries to strip end of wire)

P1: No, it's not enough. Look.

P2: You have to connect it --. (P tries to connect wire.)

P1: Where's the other wire?

P2: I have it.

P1: What are you doing? You're supposed to --.

P2: Give it --.

P1: Let me do it. Where's the wire?

P4: Don't cut it too much, eh?

P3: Here let me do it.

P2: Here, let Helen do it.

L.6-p.A99, L.35: p-M-b

Girls' interaction suggests that their activity is not random.

They appear to know what they are doing.

1 P4: Don't cut too much --.
Cut it more on a slant. Put
the pliers on a slant.

P: Slant the pliers.

5 P1: Don't you connect them
all together?

P2: Yes, but you have to
connect them like this. This
one wasn't there. You have
10 to put them all in with this.

P3: We did it again.
(Connection comes apart.)

P4: That's part of it. Oh
boy! This thing's gonna take
15 forever. Okay, I'm getting it.

P1: You gotta put it, eh ----

P4: Okay, I get it.

P1: Yeah, but you have to
put it altog --

20 P4: Now, where's our bat-
tery? Bon.

P2: Yeah, but you gotta
put it together. See?

P3: Yeah, but that one's
25 not even connected yet.

LL.1-25: p-M-b

Dialogue indicates that girls are drawing on their prior experiences with circuits.

They are still under the influence of the T's set or framework and they understand how to connect the circuit (LL.7-10).

T: (To class) Try your
light meter. See if
there's any difference,
one from the other, or
30 if they are all the same.
Check to see if they have
all the same strength.
Now first of all I forgot
one very important thing
35 didn't I? (T closes lights.)

LL.26-35: p-M-b

T guides Ps to relevant aspects of the inquiry, without telling them what results to expect.

(Microphone moved to Group II
of 4 boys. Boys have connected
2 batteries and 3 bulbs in
circuit. Boys using paper
40 light meter to test bulbs.)

(Investigator's notation)

P1: It goes on mine.

P2: Mine is 6.

P3: I can't see it on 4. I was positive I could see it on 4.

P2: Check on number 4. Check on 3.

P3: No. You can hardly see it. Okay say it's on 3. Just barely. So it's about 3 then.

P2: Yeah. It goes on at 3. Mine goes off at 3!

P1: Seven. You can see it at 6. At 4 you can't.

P1: No. You can't. Barely. Barely. So this is at 3. What's this?

P2: So this is at 3. What's this one at?

P1: Let me check. Four. This is at 4, here.

P2: 4, 4, 3.

P1: It should be all the same.

P2: Yeah, it should be.

P3: These two are 4 - unless this one's wrong.

P4: Check it all with the same one. Maybe one of them has thicker paper than the other you know. (P refers to paper light meter.)

P3: You could see it at 4.

P2: Yes you can, look at this!

P3: Yeah, just barely.

LL.15-26: F-b

Comments of $P_1$ and $P_3$ suggest that a uniform result is expected, although T does not state that a particular result is expected.

This appears to be the Ps' preconceptions of what they believe should be.

LL.27-30: p-M-b

$P_4$ suggests reason for different results. He refers to his understanding of the light meter and the group's activity in order to recognize the need for a standard meter for all the readings.

This implies that successful investigation (and results) are based on Ps' experience and understanding of context in which experiment is carried out.

So it's at 4 then.

P2: Yeah, it goes up to 4.

P3: Yeah, all of them are 4.

P4: You could see it at 5.

P3: Okay, write it down.

P4: They're all at 4?

P2: Yup. All of us had 4, Miss, exactly.

T: They're all exactly the same.

P2: All exactly at 4, Miss.

T: You didn't find any difference.

P2: Nope. No, Miss.

T: Okay. The power's the same in everyone.

P2: Yes, Miss.

P4: The power's not the same in back there.

T: (To another group) Was the power the same in every light?

P: Yes, Miss.

T: Here. (To another group) Did you get yours done yet? You're not very lady-like (to girl leaning across her desk). You're almost ready?

(Group II of 4 boys, make circuit with 1 battery and 1 bulb.)

P2: (Testing with light meter) It goes up to 1!

LL.1-14: F-b

Without knowing whether Ps used a single light meter, have to assume that they changed their results in order to achieve uniformity. They did not expect different results.

LL.4, 6, 19: p-M-b

P4 questions actions of the group. His observations are not the same as the others and he does not want to present uniform result.

This shows a reinforcement of his view of science first seen above (p.A100) and a continuation of p-M-b.

L.19

P4 does not agree with the report of a uniform result.

(Investigator's notation)

L.34-p.A102, L.30: p-M-b

Yes. Look. It goes up to 1. With one battery it goes through every one!

P3: One battery and one light bulb!

P2: And 3, and 4 and 1 (numbers on light meter). You can even see number 1!

T: Yours is okay. Over there?

P2: One battery! So we'll try with two. No. Two batteries, but with 4 bulb holders.

P1: It'll go lower.

P4: Your gonna have less power.

P2: It could work. It could work good, too!

P4: It's gonna have less power.

P2: No, no. Leave that there. It could work like this. Is that connected?

P: No.

P2: Get one for there.

P: Another one?

P2: One of these things, there. (Boys connecting a new circuit with 3 bulbs.)

P: This is dumb.

P: No put one there.

T: (To class) Be quiet now. Just for a minute, please. How many did finish their experiment?

LL.1-31: p-M-b

Same group of boys continue investigation, connecting different number of batteries and bulbs.

Ps' comments suggest random activity--Ps trying out various connections to "see" what would happen.

However, Ps' comments indicate that a relationship is made between their experience with the equipment, an understanding of circuits and the use of the light meter.

(Investigator's notation)

Classroom Management

(T counts hands.) 1, 2, 3, 4, 5. You people are still working on it?

P: We got it Miss, but then --

T: Oh, do you know how to do it?

P: Yes.

T: But what happened? Now, when an experiment doesn't work --

Ps: It worked. It worked.

T: Okay, they did work?

Ps: Yes, Miss.

T: Alright. And your light meter, did it show any difference in the power? (Ps talking and working.) Okay. That's enough for that one now. Just leave it. Okay. Leave it. Take it apart. Take it all apart. We're all finished for now. Take it apart. We're gonna do something else. Quickly. You've got, oh, one minute. (To a pupil) If your bulb doesn't work, put it in here. Find another bulb.

(Recess bell rings.) Pick up the white wires - one person per group - and the person who was responsible for the wires, pick up just the covered wire. We're gonna do something else. Okay? Keep your copper wire. Would you take a look to see if it's raining out there?

Ps: No, Miss. No, Miss.

T: Good. Get your things

LL.9-14: p-F-b

T's comment hints that something is to be done "when an experiment doesn't work". Unfortunately, T does not pursue this when Ps indicate that "it worked". T appears to approve.

Though T does not indicate what results expected, Ps believe the T expects their investigation to "work".

(The same kind of idea surfaces again on p.A112.)

LL.24-p.A104, L.1

Classroom Management

quietly now.

(Lesson continues following recess.)

T: I don't want to hear anybody talking, please. You have now, on your desks, copper wires and those copper wires are for a special reason. But I'm not telling you why. Again, you'll have to work in groups and you may find that a bit difficult. You have to try to make another type of a circuit. And this circuit - work together - will not be in series like we've done before. You're gonna try to connect your bulbs in different areas, but always going back to the power. What's the power?

P: The battery.

T: The battery. Back to the battery. Okay? You're gonna try to connect --. Now, there's a reason why this wire is not covered, and I'm gonna let you find out what you can do with it. You're gonna work by yourself before I tell you how to work it. I want you to try to connect, like you've done before, except this time the bulb - every bulb that you light goes back to the power. But not in series. Okay? See how you're gonna work it. Yes? I don't care how you connect it up. The only clue I'm giving you is this wire is not covered for a reason. (T circulates, going from one group to the other.)

Episode III: p-M-b

(L.6 - p.A108, L.20)

LL.9-10 (see below)

LL.13-45: p-M-b

T provides set or framework for Ps' experiment to avoid aimless activity.

T appears to rely on Ps' prior experience with circuits (in series) and their understanding of context of experiment.

T talks about activity using science vocabulary, implying that Ps understand the meaning of the terms and how they are used.

LL.9-10, 28-31: p-M-b (S-b)

First impression is S-b since random activity is implied. But this may be T's way of providing a "clue" to the use of wire in new circuit. Ps not told the purpose of the wire. Prior understanding of circuits is assumed.

LL.35-40: p-M-b

T reminds Ps of their prior experiences with circuits. She set the guidelines for their work --"not in series".

P: That's a clue?

T: That's a clue.

P: Not covered?

T: Okay. Sh! Please. How are you gonna do it?

P: I don't know.

T: Only one group. You've got this done. Okay, now can you connect others to go there?

Ps: Yes.

T: Fine.

P: Oh. I get it.

T: Okay. Connect one and build others around it, but that bulb has to go, to get its power, back to the battery. You know how? Well go right ahead.

P: It doesn't work.

T: Work together. Work together. Sh! Figure it out.

(Microphone moved to Group III of 4 boys.)

P1: Listen, you know why the wire's not covered? Because if you put this, eh, the end of this one, near this one, with the light eh, with light, ----.

P2: Speak louder, Todd. I can't hear you.

P1: It won't light.

P3: Let's try it with the fahnestock clip. You see if the light is this way --.

LL.8-21: p-M-b

T guides Ps in their work by suggesting a connection. Aimless activity is prevented.

T does not provide Ps with information about results.

LL.14-19

This is the supporting "clue". T assumes Ps' experience helps them understand her "directions".

P1: All I want is to get ----.

P2: Can't hear you, Todd.

P1: Be quiet, okay.

P2: If you just get closer.

P1: That's why the teacher gave us the clue.

Ps: We'll have to be twisting it around a little.

P: Let's add up all our wires.

P: This wires me to Steve.

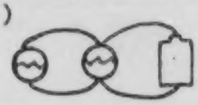
P: That's not the right one. That one goes this way.

P4: And those two are for the battery?

P: It's this one.

P: Now watch. I think I can get it in.

P: That one's for the lights. (Ps connect wires in circuit.)



P: Yeah. Hold onto that one.

P: Miss, I know why it's not covered. Because if it's not covered it won't work.

P: It doesn't have to be covered to work.

P: Most of them have to be.

P: Yeah, but this is copper. This is copper.

LL.6-24: p-M-b

Ps appear to be working in a random fashion; however, the result is a plausible circuit (LL.20-23), one which follows T's guidelines that every bulb goes back to the power.

Result of investigation is clue that Ps depend on their experience and understanding of circuits, without T information as to how to set up circuit.

(Unfortunately investigator did not make note of placement of uncovered copper wire.)

L.25-p.A107, L.9: p-M-c

Ps' explanation appears to rely on experience with circuits and some information acquired in other ways.

Ps use scientific vocabulary with some understanding of conduction in the circuit box (p.A107, LL.1-4).

P: Well, if you put a penny in the circuit box, I know, like, eh - it'll go through eh? I heard somebody say that.

T: Yes, but don't you ever do it.

P: A short-circuit, or something.

P: Okay, that's them all.

LL.10-18

Dialogue unrelated to task.

P: If you put sugar in the gas tank - ha.

P: That's bad.

P: Ha. I did that.

P: When? On Monday? I never go out on Monday.

P: It goes something like this.

P: Take the fahnestock clips off - all the way. Okay don't attach it yet. Okay, now attach this one. That's it.

P: It won't work.

P: That's just the way I did it.

P: They're babies, over there.

L.27-p.A108, L.20

Inadequate clues in Ps' dialogue for analysis

First impression is aimless activity and thus S-b.

P: Well let them do it their way and see if it works.

P: I'm working with the brain, here.

P: That's a point.

T: Okay, please. Alright. Sh! Sh!

P: The copper wire does not work.

P: Pull it. Okay.

P: What are you guys doing?

P: Just never mind us.

P: Pretend we're on both of ours.

P: Yeah, get out of here.

P: I need another battery.

P: Here, use mine.

T: I have one group who has it. (T refers to Group IV of 4 girls who lean over the desks to cover their completed circuit with their arms and bodies.)

P: Let's see. Oh, I saw it.

P: Real close?

T: Okay. Pay attention now. Over here everybody.

P: I got it!

P: Okay.

T: You have a battery, okay, uncovered wire, copper wire. Now do we have covered wire in our walls?

Ps: No. Yes. No.

T: Well, why?

P: 'cause if they're not covered, like the wires could touch and short circuit.

LL.12-17

Insufficient evidence to analyze.

T could be recognizing circuit she expects, in which case clue would be F-b.

But could also be a recognition of successful investigation because of Ps' application of their understanding and experience to the task. This would be a continuation of p-M-b.

Episode IV

(L.21 - p.A113, L.35)

LL.32-35: p-M-c

P appears to understand meaning of term short circuit in context of T's comment.

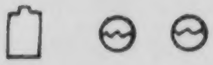
T: Yes. Okay. Pardon?

P: If the wires get, like, interesting point. If I left lights burning for an hour or over like that like, the wires could get burnt.

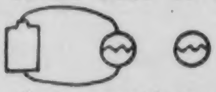
T: Exactly. We can't do it. But can we do it here with our battery?

P: No. No.

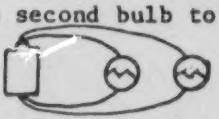
T: Yes, we can. But we don't use a covered wire. But to learn about a different kind of circuit, we can use it. Now when I said go back to the same power. This is your power. (T draws sketch on chalkboard and points to battery.)



Use one battery, 2 batteries. It doesn't matter. But you must always go back to the same power. I can have one there. (T draws 2 lines from first bulb to battery.)



I can have another one here. (T draws second set of lines from second bulb to battery.)



You understand what I'm talking about?

P: Oh, yeah.

T: Okay. When I said go back to the same source. Okay. Now. Is there another way that it can be done? I can go on that side. I can go anywheres

LL.13-37: p-M-c

T's diagrams help her provide a framework for the subsequent explanations by the Ps.

T's explanation relates the information she wishes them to have with their own experience and their understanding of circuits.

T uses scientific vocabulary which Ps understand (LL.29-32) in the context of T's diagrams and explanation.

L.34-p.A110, L.16: p-M-c

T encourages Ps to relate the science information given to their own experiences in order to solve the problem set.

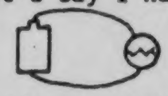
1 (sic) I want with it, as
long as I go back to --
(T taps sketch of battery
with chalk.)

5 Ps: The source of power.

T: The source of power.
Okay. Can you think of
another way I could do it?

P: No.

10 T: Let's say I have this:



Can I add more without going
back to this? (T points to
battery.)

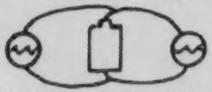
Ps: Yes. Yes.

15 T: Where would I have the
wires?

P: On the bottom.

P: On the --

T: Come and show me. How
20 could I work it? Sh! Sh!
(P goes to chalkboard and
draws set of lines from bulb.)



Would it work the way he has
it?

25 Ps: No. Yes.

T: Will it work?

Ps: Yes. Perhaps.
(confusion)

T: How many say it will
30 work? How many say it
won't work? Why?

P: Well, I don't know.
(Ps laugh.)

Ps and T use complex, scientific vocabulary when talking about the problem.

T uses drawing of circuit familiar to Ps as basis of her questions.

LL.20-32: p-M-c

P makes sense out of new problem by drawing on prior experience and understanding of simple circuit.

Same ideas continue to be reflected by Ps on p.A111 until L.19.

1 T: It will work because
he's going back to the power.
Sh. Sh. Sh. Can I have
power going somewheres (sic)
5 else?

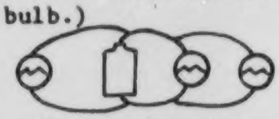
P: Yes. Yes.

T: Where? He cut these wires.
(Points to P's diagram.) Can I
go another way?

10 P: Yes, Miss.

T: How? Show me. These
are my 2 wires. Don't worry
about mine. What are you
going to do?

15 P: I'm gonna do this. (P
draws 2 new sets of wires
and bulb.)

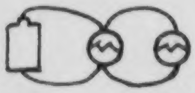


T: Well, you're doing the
same thing.

20 Ps: Oh. Miss! Miss!

T: Okay. Yes, Nadia.
Erase that. It's good, but
it's not what I expected.
Sh. Sh. Nadia do you have
25 any other way? Where else
could I put the bulb?

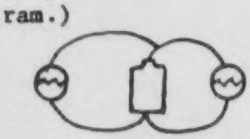
Nadia: Yes, Miss. (P draws
diagram.)



T: That's the same as this
30 only it's outside. No. I'm
talking about something else.
One more and that's it. Then
I'll have to tell you 'cause
I don't have time to --.

35 P: I've got it.

T: Okay, try it. (P goes to
board and draws diagram.)



LL.15-17: F-c; (p-M-c)

Successful diagram indicates Ps made sense out of new problem by referring to prior understanding of simple circuits.

LL.21-26: F-c

T expects a particular explanation of circuit, which fits her own understanding. (She gives limited acceptance to Ps' correct diagrams.)

LL.29-34: F-c

T rejects P's diagram which does not conform to her expectations.

P: No. Miss, it's the same way.

T: The same thing again.

Ps: Oh. Miss, oh!

P: But it's on the battery and on the wire.

T: It's on the battery and on the wire. Would that work?

Ps: Yes. Yes.

P: I don't know.

T: You think so. You have that? What do you call this part? Sh! (To noisy Ps.) Please. Sh! Sh! That's enough now. No - more - talking. Quiet.

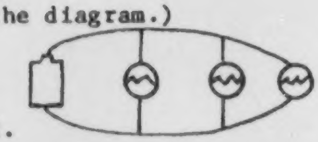
P: Miss, we did it, but it doesn't light.

P: Aah!

T: If it doesn't light there's something wrong with it then. You try to find out why. (To class) Pay attention here, now. No one thought of this one.

P: Which one?

(T draws the diagram.)



P: I did.

P: Oh. I knew it. I told you guys to do that.

P: Oh, sure!

T: Would that work?

Ps: Yes.

LL.1-11: F-c

T rejects P's drawn explanation again -- overriding P's attempt to support the drawing (LL.5-6).

LL.9-10

Suggests that Ps do not know what T expects.

LL.17-25: p-F-b

Expected results are not achieved (LL.17-18).

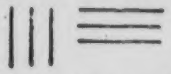
T indicates something is wrong but she doesn't say what that is. Ps expected to find out.

(Note: Same kind of T comment on p.A103.)

LL.25-33: F-c

T's explanation of parallel circuit derived from her understanding. She ignores Ps' understanding and their diagrams.

T: Now that has another name. What do you think --? Look at this. What does that suggest? There, there, there, there, there. (T draws lines on the chalkboard.)



What name would we have for that?

P: There, there (laughing).

P: The there, there.

T: I don't need that, Albert. Alright. What do we call these? These lines are --.

P: Four stripes.

P: Parallel.

T: What are they? What are those lines? (Points to circuit drawn.)

Ps: Parallel.

T: Parallel. And this was a --

Ps: Parallel circuit.

T: Okay. We did a series and we did a parallel. I told you a long time ago that we would learn parallel circuit and yet no one remembered that I'd mentioned that.

P: I did.

P: I did.

Ps: I did.

T: No more. Okay everybody. Sh. Sh. Please take everything apart. Sh. Sh.

LL.1-8: F-c

T expects particular explanation that she considers acceptable.
She provides a rule for a parallel circuit based on parallel lines.
T's explanation is not related to Ps' drawn circuits.

LL.7, 17-18, 21-30: F-c

T insists that Ps use term parallel without linking the parallel lines with use of the term in the context of the circuit.

L.34-p.A114, L.19

Classroom Management

Quietly. Quiet, please. Some people are forgetting themselves. Quickly. Will the same people who gave out the materials pick up please. The same people. Pick up what you gave out. (Ps noisily collecting supplies.) Would you please take out your copybook now. Please hurry with the pick up. You're too slow this after noon. Come on. Brian, sit down. Michael there's still some over there. Pick them up. Go check around to see if everything's picked up. Now, no more talking. Take your copybook quickly. What I want you to do is state - I'll put it on the board. First of all --. (T writes on chalkboard and Ps copy the following into copybooks:)

1. Did the bulbs become brighter, dimmer or stay the same when you used the light meter on the series circuits?

2. Sketch a parallel circuit.

T: (Reads question 1 aloud.) Okay. On all those bulbs, did they remain the same? So that's a question and you know you must answer in sentence form. Once you're finished that, I want you, and I hope you understood what I meant by a parallel circuit. Sketch a parallel circuit. I don't have time for more today. We'll do the testing another time. (Ps work at their desks. T circulates.) Next time we'll try the light meter on a parallel circuit and

Episode V

(L.20 - p.A116, L.21)

LL.26-31: S-b (S-a)

Question requires information derived from Ps' experience. Instead of talking about the results of the investigation, they are expected to write them out.
This question could also be a request for the Ps' observations made during the investigation.

LL.32-33 and 39-42: F-c

T's comment and question suggest a particular drawing is required, irrespective of Ps' understandings.

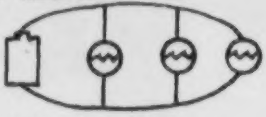
Implication here that the drawing would be the rule to indicate Ps' understanding of parallel circuits.

we'll be able to compare both circuits. Today we just did not have time. For a change you're drawing your circuits properly, and label it. Give it a name.

P: Parallel circuit.

T: Parallel circuit, right.

(Group II boys all draw the same sketch.)



T: Do you think we could make a parallel circuit with this kind of wire (holds up covered wire)?

Ps: Yes.

T: How could we do it?

P: Uncover the wire.

P: Take off the outside of it and --.

P: Strip it.

T: I know but that would be dangerous wouldn't it, if we did it in our walls. Could they do it in our walls?

Ps: No.

T: No. What would they do?

P: They'd have a cable over it. Not a cable but a --.

P: Oh, I know. They cut little slots.

T: Exactly. They would, like we see all over the place, eh, how they're special in casings. Okay, going back to the power all

LL.4-11: F-c

T notes Ps' drawings with approval, confirming her expectations.

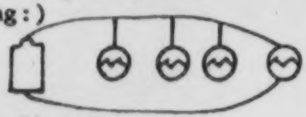
LL.12-35: p-M-c

T tries to relate Ps' experience with both types of wires, but she provides only limited explanation.

Ps' comments indicate that they relate their experiences with a limited knowledge acquired in some other way.

the time. Okay. Fine.

(One boy in Group VI draws the following:)



T: (To one P) Okay. Just as long as your battery --. You have a north and a south pole here. Okay. Now what did you do? You've got 2 north poles. Would it work? You'd better try it.

P: Miss do we have to label our parallel circuit?

T: That's what I said. Give it a ---- from your ---- What is this called?

P: Dry cell.

T: Put your work away, as soon as possible, quietly. I'll give you another minute or so.

(End of lesson.)

LL.1-4: F-c

Ps' diagram does not meet T's expectations.

LL.4-21

Confused dialogue.
Not possible to analyze.

## SCIENCE LESSON - 04

## Rocks and Charts

(The lesson begins.)

Teacher: OK. Sandy do you want to tell us something about last week's rocks? Speak clearly so that we can all hear you.

Sandy: Like when we press one rock, the black one, it feels wet.

T: OK. Ruth?

Ruth: Some rocks were ---- .

T: They're layered. That's good. Tracy?

Tracy: Some were rough. Some are smooth.

T: OK. Kevin?

Kevin: Some of them were bumpy.

T: ---- .

P: Some were shiny.

Cathy: Some were like sand.

T: They felt rough like sand. Alright. Sandy?

Sandy: ---- what colour it was. The white rock ---- .

T: Spots came off?

Sandy: When you rubbed it.

T: When you rubbed it spots would come off. OK. Judy?

Judy: If they're layered.

T: Right. If they're layered. OK. Yes?

Episode I: S-a; (p-M-a)

(L.1 - p.A118, L.26)

LL.1-3,10,19-20: S-a

T solicits and accepts descriptions based on sensory observations.

LL.5-7,12,15: S-a

Ps' descriptions are result of random sensory observations.

LL.18-19: S-a

P recognizes texture of rock by refering to sand, with which she is familiar.

T prefers a descriptive, sensory term -- rough.

P: Some rocks, you can cut something with them, like scissors or something. Like the number 1 rock it was easy to cut the plastic. (P refers to plastic egg carton holding rocks.)

T: OK. So what will we say then -- ?

P: Sharp?

T: Sharp! The edges are sharp. Yes, Richard?

Richard: You can skim one of the rocks, the thin rock. You can skim it.

T: Oh, that's right. Yes. Skim it on the water. You said it was so flat.

Richard: Yeah.

T: Good. Benoit?

Benoit: Number 4 rock was very rough.

T: Good.

P: One of the rocks was soft and chalky.

T: OK. It was soft and chalky possibly ---- . OK. Shall we look at some new rocks today?

Ps: (In chorus) Yes.

T: We have some new rocks today and we'll see what we can discover about these. Last week we had rocks 1, 2, 3, 4. Now we have 5, 6, 7, 8, 9. (T distributes an egg carton containing 5 rocks to each pair of pupils.)

P: Oh, 5 rocks.

(Ps work in pairs examining the rocks, talking together. T

LL.1-6: p-M-a

P appears to apply what he knows about other (sharp) objects to the observed characteristics of the sample rock.

LL.7-10: S-a

T turns P's comment to a sensory description.

LL.12-14: p-M-a

P links the shape of the sample to his own experience skimming rocks.

LL.15-17: S-a

T turns P's observation to a sensory description.

LL.20-25: S-a

Description by T and Ps based on sensory observations.

Episode II: S-a

(L.29 - p.A133, L.30)

LL.30-31: S-a

T refers to discovering something about new rocks. (Context of dialogue implies sensory observations may provide "new" information.)

circulates, talking with each pair. Not possible to distinguish all of Ps' dialogue.)

P: Miss, is this a rock?

P: It's heavy like a rock.

P: This isn't a rock.

P: I can't.

P: Where did you get this one?

T: Now. Let's begin by, maybe we could play our game. Remember last week we played a little game and someone gave a clue?

Ps: Oh yeah!

T: OK. Good. One clue. Kathline?

Kathline: It feels like plastic.

T: It feels like plastic. Give an answer, Kevin.

Kevin: Um, rock number 5.

T: Is he right, Kathline?

Kathline: Yes.

T: Yes. Good. Deena?

Deena: A rock that is smooth and easy to break.

T: I'm sorry. I didn't hear you dear.

Deena: A rock that's smooth and easy to break.

T: Smooth and easy to break. Tracy?

Tracy: Number 5.

LL.5-31: S-a

Ps present and T accepts random observations.

LL.5,18,25: S-a

Ps perceive what is concrete and obvious to them.

T and Ps use simple, non-scientific language when talking about observations.

T: John?

John: A rock that's shiny.

T: A rock that's shiny. Ruth?

Ruth: Number 9.

T: Number 9? Good. Lulu?

Lulu: Ah, a rock that is heavy.

T: A rock that's heavy. One clue.

P: The last one ---- .

T: Nine?

Lulu: Yes.

T: Right. Sandy?

Sandy: A rock that is light and has many - uh, three colours on it.

T: A rock with three colours. (Ps' hands up.) Robert?

Robert: It's rock number 7.

T: Rock number 7. ---- Oh, these are very easy. Alright Danny, a clue?

Danny: (Picks up rock.) A clue, ah ---- .

T: Oh no. You're not supposed to pick the rock up. Everyone will know which one you have. Pick another one.

Danny: Um, it has little spots on it.

Ps: (Hands up.) Oh, Miss!

T: Benoit.

Benoit: Rock number 7.

P: Yes.

L.1-p.A121, L.16: S-a

Ps provide and T accepts random sense-data information about rocks.

T and Ps use non-scientific language.

T repeats Ps' simple descriptions.

LL.6, 13-15, 27: S-a

Evidence of Ps' reference to obvious sensory characteristics.

LL.23-26: S-a

Evidence of importance T places on what is easily observed (seen).

T: Tania.

Tania: It's smooth and shiny.

T: It's smooth and shiny. Jimmy, which one is she speaking about?

Jimmy: It's, ah, smooth. Number 5?

T: Number 5? Tania?

Tania: No.

T: No Jimmy. She has to give you another clue. Give him another clue.

Tania: It's silver.

T: It's silver.

Jimmy: Nine?

T: Nine? Is he right? Alright, now let's talk about our rocks. Tania, tell me something about one of the rocks. Let's start with rock number 5. Tell me something about it. Go ahead.

Tania: It's black and it's really thin and it feels like plastic.

P: Miss, Miss!

T: All quiet now. We're gonna all have something to tell about it. Avy?

Avy: It's layered.

T: It's layered! Avy says it's layered. Cathy?

Cathy: You can see -- we can see ourselves in it.

T: Oh, you can see yourself in it? Like a mirror?

LL.2-6: S-a

Information about rocks through use of senses.

LL.10-14: S-a

T requests further information. She accepts and repeats P's description.

LL.17-21: S-a

T solicits information without suggesting what to look for.

L.22-p.A122, L.31: S-a

Ps and T talk about observations using simple, non-scientific language based on use of their senses.

LL.32-35: S-a

P and T use simple vocabulary rather than scientific term "reflection".

Ps: Yeah, uh huh. ---- (Hands up).

Ps: It's shiny.

T: Can you? It's shiny? Good. Danny?

Danny: It has gold spots on part of it.

T: Alright. Tracy?

Tracy: ---- .

Sandy: It has 3 colours.

LL.10-18: S-a

Observations are based on sense-data information.

T: About 3 colours. What 3 colours would you say?

Sandy: One's black, brown, and like, white like.

T: Black, brown and -- ?

Sandy: More silver.

T: Alright. Kevin?

Kevin: It is light.

T: Oh, someone else I think, already told us that. OK. Something else now, that no one else has said about rock number 5. Let's see.

LL.21-27: S-a

T solicits new information about rocks and she continues to accept sensory descriptions.

Ps: Oh. Um.

T: Melina?

Melina: It's smooth...

T: It's smooth. OK.

Melina: ...and when a piece falls off it looks like paper.

T: Alright. When a piece falls off it's a little like paper. OK.

Kevin: Miss, I know a good one.

1 T: Yes. What's a good one,
Kevin?

Kevin: It shows, if you rub it
like, it'll show little gold
5 spots on it. It'll like come
off! (P holds up his fingers
to show little flecks on them.)

T: So. Little pieces come off?
What are the little pieces like
10 when they come off, Kevin?

Kevin: They look like little
pieces of gold or something like
that. Spikes!

T: OK. Good. OK. Regie?

15 Regie: You can see through it.

T: Transparent? Maybe.

Ps: Yeah.

P: Miss, mine is transparent.

T: OK. Yes Robert?

20 Robert: It feels like a fish,
you know, like these things,
these gold spots like fish -- .

T: Like scales on a fish?

Robert: Yeah.

25 T: Ah, good. OK. Kevin?

Kevin: You can skim it.

T: You think you can skim it?

Ps: Yeah. It floats.

P: It'll float.

30 T: Oh, it's a rock that will
float? Oh good. OK. That's
different isn't it? Richard, do
you think you could skim it?

Richard: Yeah, but you have to

LL.8-14: S-a

T solicits further information. She accepts a sensory reference to "gold" which P associates with a particular colour.

LL.15-19: S-a

Following P's comment, T (now) uses scientific term which is repeated by another P. (No evidence to suggest that Ps understand meaning of term. T may be developing M-a.)

LL.20-25: S-a

Link to scales of fish still refers to sensory perception.

LL.26 - p.A124, L.1: p-M-c

Ps' comments not based purely on sense-data information. Explanation implies Ps are drawing on understanding that an object can be skimmed if it floats. (Similar reference to skimming of rock first seen on p.A118, LL.12-14.)

LL.30-31: S-c

T accepts comment without question, or clarification.

whip it pretty hard.

P: And he might have to make sure that there's no wind, 'cause if there's wind it'll like - whew - blow away 'cause it's so light.

Ps: Yeah.

T: OK. Now let's look at rock number 6, if we see anything different about it. John.

John: It's light.

T: It's light. OK.

Ps: Oh, oh! Yeah! It is.

T: Stephanie?

Stephanie: It's very rough.

T: It's very rough.

P: It's like a ball of string. Feel it.

T: Robert.

Robert: It's like a piece of dried sponge.

T: It feels like a piece of dried sponge. Very descriptive. Good. Um, Kathline.

Kathline: When you rub it, some white sand comes off.

T: When you rub it, white sand comes off. Melina.

Melina: And it's like a greyish white.

T: Good. Kevin.

Kevin: It isn't very hard.

T: Jimmy?

LL.2-6: p-M-c

P is beginning to refer to other experiences and information to explain when rock sample can be skimmed.

LL.11-19: S-a

Ps provide random sensory descriptions of rock.

LL.20-23: S-a

T encourages use of familiar, descriptive vocabulary.

L.25-p.A125, L.36: S-a

Ps talk about their observations using non-descriptive language.

They perceive what is concrete and obvious through their senses.

T repeats same terms that are used by Ps without offering further information.

Jimmy: ----

T: I don't think they heard you Jimmy. You'll have to say it louder so all the rest can -- .

Jimmy: When we squish it on the floor, on the desk, it comes like flat.

T: OK.

P: Like, sort of like -- it has little holes in it.

LL.9-17: S-a

Ps use simple, descriptive terms to report their observations.

T: It has little holes in it! There's something different we haven't heard before. Richard, do you agree it has little holes in it? Richard ---- ?

Richard: Yeah, it has little holes in it and...

T: OK, and --

Richard: ...it's sponge like.

T: OK. Danny?

LL.20-31: S-a

T solicits and accepts as much sense-data information as possible.

T does not tell Ps what to look for.

Danny: Miss, when I was knocking it on the desk some pieces fell off. (Ps agree, knocking rocks on desks.)

T: That's a different one. Tracy?

Tracy: Miss, ---- .

T: Someone else mentioned a sponge.

P: It's got air bubbles in it.

T: It has air bubbles in it. Stephanie.

Stephanie: When you rub it on your hands - like if you make an X on your hand you see that it makes the mark of an X.

Ps: Yes it does, Miss.

Ps: Hey, yes.

T: OK. Yes?

P: Miss, like it feels like dry, ah, and all kind of rough.

T: It has a crust then.

P: I know a good one. Miss, I have a good one.

T: Nothing else? No one else has anything else to tell me.

P: I have one.

T: Yes?

P: It's sort of chalky.

Ps: Yeah.

P: Yeah. You write on your hand.

P: Miss, ---- .

T: Yes? Ruth.

Ruth: Well, it looks kind of like just dry and it's rough, you know.

T: Did we ever learn about that kind of a rock anytime before?

Ps: No.

P: This one is different.

P: It's so light.

T: Danny?

Danny: I notice this one has something, ah, a fragrance on it.

T: Oh, it has a fragrance. OK. Yes?

LL.3-20: S-a

T solicits and Ps provide observations which are readily gathered through the use of their senses.

L.19-p.A127, L.10: S-a

Ps continue to present simple descriptions.

T's question (L.22) implies Ps have observed a similar rock.

T does not link prior experiences with the present observations of the sample. Ps do not recall similarities.

1 Robert: It has small coloured
spots on it.

T: Alright. You people aren't
listening to what Robert is
5 telling us. Yes?

P: When you rub it on your hand
those little silver pieces come
off.

P: Well, a lot of people said
10 that.

T: Uh hm. OK. Let's go on to
the next rock. Number 7.

Ps: Oh, yes.

T: Number 7. Alright Benoit.
15 Give us a description now, and
we'll all listen to Benoit and
he's gonna describe number 7.
Rock number 7. You look at it
and you see if you agree with
20 everything he says and maybe
you can tell me something that
he's not saying about it. OK.
Go ahead, Benoit.

Benoit: It's very heavy and it
25 could be broken. ---- and it's
a type of marble and it slivers
also.

P: Yes, Miss. Yes.

T: Alright. He did well. Tell
30 me, Richard, something else.

Richard: The insides look
cooked.

T: Pardon me?

Richard: It looks like a piece
35 of chicken.

T: It looks like a piece of
chicken!

Ps: Oh, oh!

LL.15-22: S-a

T solicits as much descriptive information as possible about the rock without telling Ps what to look for.

T does indicate that the senses should be used (look) followed by a description.

LL.25-26: p-M-a

P's brief comment implies that he has some experience with marble. He recognizes certain characteristics of his rock as similar.

1 P: Yes it does.

T: OK. John.

John: ---- when you rub it
---- pieces come off.

5 T: When you rub it on your
hand little spots ---- OK.
Now, let's not all get excited
and speak at the same time.
Kathline?

10 Kathline: ----

T: I'm sorry. I can't hear
you because I think some people
over here, Regie and Lulu, -- .

Kathline: There's a lot of
15 colours on it.

T: Oh, there's a lot -- . OK,
you tell me the colours.

Kathline: There's black, and
the colour of the skin, and red.

20 T: OK. Lulu?

Lulu: Well, there's all sorts
of colours.

T: Oh, I don't think you were
listening. Kathline was just
25 telling us that.

P: Oh, Miss!

T: Benoit?

Benoit: When you rub it on your
pants or your shirt and the
30 splinters come off onto it.

T: Frezie.

Frezie: It looks like little
gold.

T: It looks like little gold
35 bits.

L.3-p.A129, L.16: S-a

Ps present and T accepts random observations based on what is concrete through the use of the senses.

LL.14-19: S-a

Ps use sensory descriptions, which is encouraged by T. Implication that T considers such information acceptable in science.

Ps: Yeah.

T: They're valuable. Sandy?

Sandy: ---- it sparkles ---- .

T: Good. Yes?

P: It looks like it has pieces of glass in it.

Ps: It has. Oh, Miss!

T: Yes?

P: It's rough.

T: It's rough. OK. It's rough. Yes?

P: It's kind of light.

T: It's kind of light. I think someone else told me it was heavy, if I'm not mistaken. Anyone else? OK. What's the number of the next rock? Number --

Ps: 8.

T: 8. OK. Number 8. Bruce is going to describe number 8. OK Bruce, come on.

Bruce: Well, it's black and it has little sparkles on it that look white. (P turns rock over in his hands, examining it.)

T: Anything else, Bruce?

Bruce: It's sharp and you can break it easily.

P: Oh, Miss.

T: That's it, Bruce? Alright. Sandy. Something that he didn't tell us, now.

Sandy: When you rub it ---- .

LL.5-12: S-a

Random descriptions derived through use of senses.

LL.13-16: S-a

T overlooks contradiction. She solicits more, random observations.

LL.20-21: S-a

T encourages descriptive information.

LL.23-29: S-a

Ps use descriptive language.

Observations gathered through use of the senses.

P: Miss, oh, oh!

T: I didn't understand that. Would you say it again so I can understand it.

Sandy: When you rub it, you know, when I rub it on my fingers it gets a little dry and a little bit wet.

T: When you rub it, it gets a little bit dry and a little bit wet.

Sandy: That's right.

T: Silvain, since you're talking, you tell us something about it. Would you let him see it John?

Silvain: It has purple on it.

T: It has purple on it. Stephanie?

P: Miss.

Stephanie: It's rough and it's not too heavy and it's not light.

T: Kathine?

Kathline: ----

T: I'm sorry dear, I can't hear you.

Kathline: There's rust on it.

T: There's rust on it. Maybe it's just on your piece. Everybody else look at theirs and see if they all find rust on theirs. Regie over there, look at yours and see if you have a little rust on it.

Regie: Yes I do, Miss.

T: Yes? Kevin.

Kevin: I notice that it's cold.

LL.5-11: S-a

P presents contradictory sensory description.

T accepts contradiction without providing clarification.

LL.16-36: S-a

Ps talk about random observations using simple, descriptive language.

LL.27-33: S-a

T encourages Ps to use their senses in examining the rock. Implication that such observations may provide new information.

T: Oh, it's cold. When you touch it, it's cold?

Kevin: Yeah. When I feel it on my cheek, it's cold.

T: Good. Did you try the others on your cheek to see if they're cold too?

Kevin: This one is not very cold, 'cause it's rough, you know, and the other ones, most of them are not cold because they're rough.

T: Oh, I see. OK.

Kevin: Only the ones that we have now are cold.

T: OK. Good. That's something different. We hadn't spoken about that before. Danny?

Danny: ---- it has one white tiny spot on it.

T: One white spot. Maybe everybody's doesn't have a white spot. Over here, this little group of three were doing a lot of talking. Lulu?

Lulu: ---- .

T: I know. That's exactly what somebody else said. You see, if you'd have been listening, you'd have heard them say that. Alright?

P: This one?

T: The same one. We're still on it.

P: ---- to touch.

T: To touch? Then we will say it is -- .

P: Sharp.

LL.1-15: S-a

P's sensory description includes a comparison between sample rocks.

T provides no further information.

Implication, here, that random observations can generate understanding of rocks.

LL.23-35

Classroom Management

T: It has sh -- .

P: Miss, I said sharp edges.

T: Sharp. Yes, you said it had sharp edges. Alright. I think we've pretty well described that one. Let's go to the last one we have. Number 9. (Ps' hands up.) Melina, tell us something about number 9.

Melina: It's seems like it's brass or something.

T: OK. Tracy?

Tracy: It's heavy.

T: It's heavy. Sharon?

Sharon: Miss, it's shiny and it has a little bit of rust on it.

T: OK. Tania.

Tania: It looks like a piece of silver.

T: It looks like a piece of silver. Danny?

Danny: It has gold spots and black spots.

T: Richard (A).

Richard (A): Miss, it's copper, isn't it?

P: No, it isn't.

T: What do you think, Richard?

Richard (A): I think it's copper, 'cause Richard last year had a bunch of the same as this.

T: Oh. Is it the same Richard as you had last year?

Richard: No, Miss, mine wasn't

LL.3-6: S-a

T's comment implies that descriptions are expected when making observations in science.

L.10-p.A133, L.3: S-a

Ps refer to metals as if they have some knowledge of these. (The evidence is insufficient to consider the development of M-a.)

Other Ps talk about rock in terms of sensory characteristics -- heavy, silver, spots.

LL.26-29: S-a

P asks T for confirmation of identity of sample. T avoids request, implying Ps continued observations might generate answers.

copper. I think it's brass.

Richard (A): You said it was copper.

T: Oh. Kevin?

Kevin: It has layers, and it sort of has cubes too. See the little cubes?

LL.5-25: S-a

Ps talk about rocks using simple, descriptive vocabulary.

T: Oh, layers and cubes too. OK. Sandy?

Sandy: It's like it comes from something. Like it comes from something - like something broke off.

T: OK. Do you agree Silvain? You tell me something about it.

Silvain: ----

P: Here it's all scratches ---- .

LL.17-21: S-a

Characteristic of rock is evident through use of senses.

T: Regie.

Regie: It's got pieces that are lighter and smooth.

T: Is that the last rock we had?

Ps: Yes.

T: OK. Now, oh Jimmy?

Jimmy: It writes ---- .

T: It writes. On your desk, it makes a mark? That's another thing we'll do another day. Now I want to ask you about something. In grade I we used to have science like this I remember and we used to have magnets. How many remember working with magnets in grade I?

P: Oh, Miss, my brother has so much of them.

T: OK. How many know what a magnet it? (Hands up. Ps: Oh, Miss.) I guess we all do, then. Oh good. OK. Now put your hands down. I'm going to give you a little magnet and you're going to see if any of the rocks there are...

P: ...stick.

T: Stick to the magnet. Yes.

P: A magnet is a piece of metal and like sort of sticks to something that is -- like can stick.

T: Right. You can practice with the magnet, alright? Now that means that you're going to have to try every rock. OK? Share the magnet and work together. (T hands a magnet to each group.)

(Ps work with magnets, testing each rock. T circulates, questioning Ps. Ps noisily interacting. Sounds of rocks hitting desks. Unable to transcribe individual comments.)

T: Alright. Let's try rock number 5 and see if it's attracted to the magnet.

P: Yes, Miss.

P: No, Miss!

T: Now, take your time to try it.

P: Miss, it sort of is!

P: It is.

P: I know. I know what rock it is. Number 8!

P: What is it?

P: Number 8. This one (holds up rock).

Episode III: S-c; S-b

(L.1-p.A135, L.14)

LL.1-14: S-c

T and Ps talk about magnets using non-scientific language.

T does not offer explanation of magnets, assuming Ps have had prior experience (LL.1-4).

LL.11-13: S-c

T accepts P's explanation of a magnet in non-scientific language.

L.20-p.A135, L.14: S-b

Ps freely test rocks with magnet.

T provides no information about the results to expect. She accepts Ps' decision about sample that is attracted to magnet (p.A135, L.8).

T: Is it number 8?

P: I'm trying a lot of them. I tried that one and it didn't work.

P: It attracted. Right?

P: It worked. I want to break it up.

P: Yes, it's number 8.

T: Only number 8? Very good.

P: Number 8 only, Miss, if you take a piece it'll go up like this.

P: I took a little piece. I took it right from the end.

T: OK. Please take out your copy books for science. We're going to do our chart like we did last week. Keep your magnets and keep the rocks on your desk and we'll work together.

P: Miss, I'm lucky. I don't have to work with somebody else.

P: Science (spelling word for partner).

P: With this group?

T: ---- and Benoit could sit with you. ---- can sit over with Bruce, or you and Bruce can work together because you're ---- . Alright, tell me what we were charting last week.

P: Miss, are we doing charting again?

T: Yes. A new page. Tell me, John.

John: We looked for colour.

T: Colour. Shall we do colour

LL.8-9: S-b

T accepts Ps' result of test with magnet.

LL.10-12: S-b

P talks about test using simple, descriptive language.

LL.15-29

Classroom Management

Episode IV: S-a; (S-c)

(L.30-p.A138, L.27)

LL.30-p.A137, L.9: S-a

At T's request, Ps make decisions as to the characteristics to be recorded on the chart.

Ps choose sense-data information, recorded in non-scientific terms.

again?

Ps: Yeah!

P: I think we should do all the same.

LL.3-6: S-a

Sense-data information accepted by T.

T: Alright, colour. What rocks are we going to use?

P: A, B, C, D, E.

LL.7-16

Charting Procedures

T: Last week we used -- .

P: Four. A, B, C, D.

T: Then shall we use -- these are not the same rocks ---- .

P: Those are the E, F, G, H, I.

T: Alright. (T draws lines of chart on the chalkboard. She includes the rock numbers and the word colour.) Ah, Kathline? Alright, we'll put that in at the end. Let's put some of the ones which are the same as last week.

P: Layered.

LL.20-34: S-a

Sense-data information suggested by Ps and accepted by T.

T: Layered. (T adds the word layered to chart.)

P: Feel.

T: Feel. (T adds word to chart.) OK.

P: Weight and sparkling.

T: Weight. Sparkling. (T adds both words to chart.) Another one? Someone said sparkling. Do you want to use sparkling again?

Ps: Yes.

T: OK. Do we have any that sparkle?

Ps: Yes.

P: I think. Number 9.

T: Now, what new one are we going to put on the chart?

P: It is magnet. It is magnetic.

P: It sticks.

T: OK, let's put -- attracted to magnet. (T writes on the chart.) How's that?

Lulu: That means it's attracted?

T: Right. OK? Now let's begin.

LL.5-12: S-c

P's use of term magnetic could imply understanding of meaning. (Insufficient evidence to suggest development of M-c.)

T uses descriptive vocabulary without other explanation.

T overlooks Lulu's misunderstanding.

(Chart on chalkboard)

| Rock | colour | layered | feel | weight | sparkling | attracted to magnet |
|---|---|---|---|---|---|---|
| 5E | | | | | | |
| 6F | | | | | | |
| 7G | | | | | | |
| 8H | | | | | | |
| 9I | | | | | | |

(Ps draw lines of chart in their books and begin to fill in the chart, examining rocks again as they do so. T circulates.)

LL.14-19: S-a

Chart indicates use of descriptive, non-scientific vocabulary.

T: Try to make nice, neat charts like you did last week. You made very nice charts last week.

P: (To T) If the rock is attracted to the magnet, maybe it's also radioactive.

T: Oh, no, I don't think so.

P: Should we put all the colours of number 5?

P: Yes.

T: Well yes, you have to decide on the colours.

P: We have to put all the colours of number 5.

LL.28-31: p-M-c

P's comment implies some (limited) knowledge of radioactivity -- a highly scientific term. Suggests development of attempt to explain characteristics of rock sample by drawing on other knowledge.

T: Well, you put down what you see. Like this one is white and grey. If you see more than one colour ---- OK?

P: Number 8 was the cold one, eh? I put number 8 for cold.

(As Ps finish their chart, they put their books away and take out other work. Some pairs of Ps ask each other spelling words.)

T: Some of you are very slow. Maybe you're discussing too much.

P: Is the magnet a rock?

T: Well, that is a good question to look up when we go to the library on Wednesday. You'll look that up next Wednesday.

P: What should I put for this rock?

T: (Feels rock) Well, you put down what you feel?

P: Miss something terrible happened. (Holds up 2 pieces of rock.)

T: Now we have two instead of one. OK, put it back and we have an extra. When you have finished all your charting, take your carton with the rocks and put them carefully up on the empty desk at the front, please.

P: What'll we do after?

T: Study your spelling. We're going to have a spelling test next.

P: Miss can we say it's shiny and sparkly?

T: Alright.

P: Miss, where do we put this

LL.1-4: S-a

T emphasizes need to record sense-data information.

LL.13-17: S-c

Rather than providing information in response to P's question, T expects P to carry out own research.

LL.22-p.A139, L.11

Classroom Management

(the egg carton with rocks)?

T: (Nods head toward front of room.)

P: Look, Miss! (Shows T how 2 magnets repel one another.)

T: (Takes 2 magnets and repeats the repulsion.)

P: Miss, I have lots of rocks at home.

T: OK, bring them to school next week.

(End of lesson.)

## APPENDIX B

## Transcribed Interviews

## INTERVIEW WITH TEACHER

## Mystery Powders

(The interview begins.)

Interviewer: Before I start with the questions I wanted to remind you about the purpose of our interview. It is not to evaluate you as a teacher, and certainly not to evaluate the success or the learning of the children. But rather to understand the context. What went on before, in similar lessons and what you are planning on doing next week. Some of the questions may be a little pointed but I'm looking for certain clues that will help me in analyzing the lessons.
Could you give me some idea of the kinds of things you did in the last lesson. What the children did. What your emphasis was on.

Teacher: Last week, the week before?

I: No, last week.

T: Last week we did the observation with the iodine, the purpose was to find - - the purpose, I find, in each of my science lessons has been mostly to let the pupils discover themselves, observe themselves the changes. To be honest I'm really not looking for a particular answer. Planning my lesson, I don't have a goal where they are supposed to answer this. The way ________________ has been doing it with me, I guess that you know, mostly to interest the pupils and to help them discover a little bit about science.

I: What did they do? What was their particular activity last week?

T: Last week was what we call the iodine test. So we took a wee bit of flour. They mixed a few drops of iodine, using the eye-dropper, very delicately pouring a wee bit and noticing that the powder - - depending on how fast they poured the liquid - - the powder would just spread out, melt, dissolve and maybe those that poured it very slowly noticed that the liquid kind of bubbled up. Without touching it would melt just around the drop and they each come out with - - .

I: You mean with the iodine?

T: Right. Depending on how much liquid they used, how much powder they had in their little plate, we had different observations that came out.

I: Did they use all of the powders? All five powders?

T: Yes. First of all with the flour. As soon as a drop of iodine went in, that particular part of the powder turned black right away. And they were amazed by that fact, and pouring in more, they stirred it, and the black washed out to a purple colour. And they felt it and they twisted it into a little ball in their fingers.

I: You said it depended on how they added the iodine. Was there any attempt at being perfectly accurate or careful?

T: No. The only request that I made was to drop it very slowly, a few drops at a time, in order to really let the texture dissolve the way it's suppose to. Because if they pour in 2 eyedroppers right away, well all they get is mushy powder. They can't...

I: Would that have changed their observations sufficiently for them to have a different opinion of what was happening?

T: Yes, because some of them did pour a lot right away, two eyedroppers and they never had a chance to see the bubbling up of the powder. Their observation was, right away, "Everything is dissolved. Nothing happens." So then I got them to go to somebody else's desk, or to take more powder themselves and to try slowly, pouring only a few drops. Those who put only two or three drops, when the others observed that it was sticky, well theirs wasn't sticky - - there wasn't enough liquid. So they stirred it again and they poured in more to - - . It becomes a challenge between themselves, you know. One says, "I've obtained this" or "I've observed this" and the one next to him or next to her wants to have the same results. In order to have the same results, they have to work it out so that the powder will - - .

I: The children don't usually get the same results in any case, at least not exactly.

T: No, not exactly. The sugar turned a goldish. It spread out but it didn't spread out evenly. Again according on (sic) the amount that they had - - how many drops they had poured in. It left a shiny surface. They told me they could see the crystals.

I: They did the same thing with the cornstarch.

T: Right.

I: And how did they explain the similarity between the cornstarch and the flour?

T: Um. The complexion or the composure of the powders were almost the same but some were more curious and they tasted it and by tasting it - - not with the iodine though. Not last week. Last week it was forbidden to taste.

I: I meant with the iodine. The flour turned purple but so did the cornstarch. How did they explain that?

T: The cornstarch was more liquid than the powder. The powder, to use their term, made more like a dough, than the cornstarch. The cornstarch was very sticky, but it - - they tried rolling it in their hands.

I: Was that a sufficient explanation for them? Did you add any explanation to that?

T: On my own? No. With this I went according to what had been done in my room a few years back when I had been told that I was not supposed to - - I was supposed to be satisfied with what the pupils found. Now whether this is the right approach, I really - - .

I: So there was no reference to any chemical reaction that occurred.

T: No.

I: Alright. Now let's go to today's class. Today's class was a continuation.

T: Right.

I: They did the heat test and they were ...

T: It's the last one that we do before we go into mixing the powders.

I: So then they did a lot of observation, as they were carrying out the test. Um, what do you yourself consider to be the purpose of observations, of these experiments?

T: The purpose, I find - - language arts I find that they get to improve their vocabulary, by not being forced but being almost squeezed into find out the proper term, the proper word for the reaction that they find in the powders. (Long pause).

I: Well, for example, as you were walking around you kept saying to them "Are you watching carefully? Have you seen what happens? Go over to look at one desk and go to see at another desk." There seemed to be an encouragement that they observe what is happening very carefully.

T: Right, because so little does happen and, as you notice yourself, two or three fellows in the corner who were fooling around, well I had to try and interest those ones (sic) continuously, so that they will get something from the lesson. 's not only to pass the 45 minutes and say well we did science today. They have to retain something and mostly - maybe not for this year but for the future - we start by very simple things now. But if I cannot get their interest on those small lessons, observations, well - - . To me, I feel that I missed my purpose.

I: For science?

T: For science. Oh yes.

I: You know, there was a point where the children noticed there was a difference between the action with the salt crystals and the sugar crystals. It was a very interesting observation on their part. And I noticed that you tried to draw an explanation from them. They had some difficulties. Do you know why?

T: Yes, because they do not know which chemical - - which product is contained in each of these powders.

I: So is it important for them to be given that information?

T: I don't think so, because I - - . It might have satisfied them for the moment, now, but what would they have retained from the names I could have given them?

I: So what have they retained up till now? They know that something different happened. How is it going to help them in understanding science?

T: Well, to me they discovered that the chemical in salt will - - the salt has the particularity that will put out a fire and with the sugar, the chemical in it melts and becomes - - . Oh boy!

I: Let me help a little bit. Are you trying to say, and tell me if I'm wrong in interpreting this, that the composition of these two different crystals then act differently under the same kind of conditions and that would stay with them as an understanding in science?

T: To them, all they're aware of up to now is the crystals from both powders always had the same reaction in every previous lesson and today, it was a shock to them, because the reaction was very different from what they had seen up to now.

I: In other words observations can be deceiving. Up till now their observations have been the same for a variety of tests and suddenly there's a test that created some difference.

T: But to the point of being disappointed in it, I don't think - - . It was a discovery for them too.

I: I don't think they were disappointed. Do you recall the question, or was it a statement, that one youngster made about the softening of the aluminum dish? (T: Uh huh.) He was also trying to explain it and you helped him by saying that the heat would soften and stretch it. How much explanation do they really need? Now that was something not directly involved with their test and yet he showed an inquisitive nature in that respect. How much explanation do you think they really need?

T: To the point where there will be no other questions following. And to me this is a sign that the explanation is sufficient, that they are satisfied with - - . That's my feeling though.

I: At a couple of places in their work there was reference made to their own experiences at home. For example with the salt and again with the sugar as well. They recognized the caramel in the sugar and you had to draw out something about the salt. Do you try to bring in the personal experiences as much as possible?

T: Yes, but I find it very difficult to. I always try to stay in the same line of thinking that ________________ had given me. Automatically they'll come and say, "Oh, this is dough. This is maple syrup."

I: They put a label on it.

T: Yes. They go to a conclusion right away. And I find that part is very difficult to turn their - - , because in a way they are right. It looks like - but it is not, and I find it hard, for myself, to come out with questions that will awaken them enough so that they'll realize that it is not. It looks like maple syrup but as I'm telling them, "what is maple syrup?" When you turn the question around like that, well they get kind of stuck and we'll start all over the procedure. The first day, when we came out with the mystery powder, with every sense, fine OK, then "ah, it's dough", "ah, it's cake", ah, it's - - . Right away they had a label, as you mentioned.

I: And what are you planning for the next lesson, next week?

T: Next week, I will be mixing powders. Next week, though, they will work on their own. We'll do the water test with the mixed powder. They will have, according to the observation of the day and according to all their notes that they've taken.

I: They have these on charts?

T: These (pointing to chalkboard) they will copy tomorrow morning into their scrapbook. And they will have to discover what powders I have mixed together.

I: They'll carry out each of the tests.

T: Uh huh.

(End of interview.)

# INTERVIEW WITH TEACHER

## Seed Formation and Dispersal

(The interview begins.)

Interviewer: The purpose of this interview is not to evaluate you or your teaching methods and certainly not to evaluate the children. The actual purpose is to try to get the context of the lesson. In other words for me to acquire some clues to apply to the analysis. When I analyse the lesson and use the scheme, I may need something. Sometimes there is something vague in the lesson and I use the interview to clarify it. (T: Okay.) I'll ask you a few questions about the childrens' prior understandings and what you meant by certain phrases that were used during the lesson. Could you give some idea about the lesson that preceded this one? What exactly did it entail? What were your emphases and purpose of the lesson?

Teacher: The last lesson dealt with the development of the flower. Actually the last two lessons. We've been talking about the parts of the flower. They hadn't had to memorize them, just be aware of them. And we discussed how the pollen was spread by insects and by the wind. We saw two films on that, two short films, and we discussed the fertilization process where the pollen grows a tube and goes down into the ovary to fertilize the eggs. So basically we discussed reproduction in the flower. A lot of the discussion, also, turned toward people and animals which they have a little more interest in, I think. We'll be doing a human awareness family life series later on, so I just let it go with it. Basically it was covering the flower, what it's there for, the fact that it is temporary, not permanent, and what its function is and what happens to the flower once the two functions have taken place.

I: Did a lot of the information come from the children's own experience or did you have to provide some of the background information for them?

T: I have to say, in this case, that almost all the information came from me. They seem to understand very little on what flowers were. At the very beginning they thought plants and flowers were the same thing. It was hard to get them to understand that the flower is only part of a plant. And it's the same thing with people. Our sex organs are only a part of our body, and not even vital at that perhaps. So there's very little understanding of what goes on inside a flower.

I: By giving them all of this information, does this help them understand the reproductive process in general in plants?

T: Yes. I would think so. Especially since our discussion used comparisons of people and animals and their organs, and their reproductive system to compare the male parts of the plant and the female parts and how it works.

I: And was there any follow up with an investigation of plants?

T: Yes. We had some tulips, which now are dead hanging on the notice board outside, but that was passed around with a magnifying glass and they looked at the parts inside. There were two kinds of plants that they looked at plus the model which is not realistic but is accurate.

I: So would you say that the information that you gave - - rather that their investigation corroborated the information that you gave? Did it add to any information?

T: Yes. Well the fact was that the tulip is an excellent plant because the female part, the pistil, is very big and the stamens are good so they could really see the parts. They had pollen on their fingers that they each rubbed off and they could see the pollen that had also attached itself to a stigma. So that really helped to clarify things, I think.

I: So the investigation came after the information, not before.

T: Yes.

I: Then for this lesson, I notice that, well basically this was to review.

T: Yes basically a review. We hadn't gone into dispersal in detail, but we had mentioned that seeds should be spread around. How the seed develops inside the flower.

I: Do you often use these terms? I notice that you did not give them a definition of what it meant. Is it important for them to evolve the definition?

T: As much as possible. If they can figure out the word at all from the context, I'd rather not give it right in the beginning and say this is what we are talking about. If I can, I'd rather have then talk about it for a while and then give them the word later on.

I: And you said there was an experiment planned for this session. What was it going to be - - that you didn't get to?

T: Yes. Well it was basically a demonstration more than something they would do. I was going to plant, have them - - . I wanted to show the effects of dispersal as opposed to having the seeds all clumped together. So I was going to try and get from them what the procedure would be. We have a format for writing up experiments, you know, with aim, equipment, procedure and so on. I'd hoped to get - - to show them a bag of grass seeds and ask them how they might go about proving that dispersal is a better method of planting then just to clump them up together. And I had two small dishes of soil and I was hoping to get from them that they would pile one bunch of seeds all together and then sprinkle the same number around in the second dish. And then, in a matter of days, we would count how many had survived in each bunch. And I figured they would come up with that by themselves.

I: They have enough experience to figure it out.

T: If you flash the seeds around in front of their eyes long enough, you throw a few gentle hints, hopefully it would come from them what we might do.

I: If they would evolve this kind of experiment - - that's really what it would be - - they would have to make the decision as to how to set it up. (T: Right.) Would that help them understand how science is carried out in general?

T: Yes, I think they have a pretty good understanding of that because we have done a number of experiments, not so many with plants perhaps, but early on in the year we did air and the properites of air. A lot of very exciting experiments that have stuck with them. I know that, you know. And they seem to understand that you have to have an aim, which I usually give them, but then the rest they are quite capable of and the conclusion they can do themselves. And they seem to understand that there has to be steps that you go through and why scientists work in this way.

I: Has accuracy been of importance in these activities? Have you emphasized the need for accuracy at all?

T: Ah, the need for accuracy in the sense of detail, especially in the procedure section. Because on occasion I'd give them experiments to do at home, and I said, "You must follow exactly what it says there, because if you deviate from it, the experiment won't work, or it might be dangerous." And we've gone to science experiments and why they must write down things accurately in the lab in high school, and so on. Because of the fact that there is danger when you don't follow exactly. Plus the fact that results won't be the same for everybody. This is the reason that scientists write things down so that someone else can learn from their experiment and can do the same experiment and hopefully get the same results.

I: And from your point of view, how important is it for the kids to observe the detail of experiments?

T: Yes. Obviously yes. For one reason it helps them to just remember the thing. I mean, they'll forget this diagram (points to diagram on the chalkboard) and the various parts. You know I have to memorize the thing myself every year. But I do know what the parts inside are for, and I think that will stay with them. And the experiments we did earlier on on air pressure and so on, they may not remember the exact details or how many pounds per square inch, but they do know that you can crush a can with air pressure and that a piece of cardboard stuck on a glass upside down with water in it will stay on because of air pressure.

I: Because of air pressure. Now that's interesting. How do they account for what they see? When they carry out experiments or activities in the class, how do they account for the fact that the air pressure will keep the card up? What kind of explanation comes through?

T: At the time they understood that because the glass is full of water there was no air in it, but there was air pressure around it in the room which was holding the cardboard on even when the glass was upside down. They understood that there was more air pressure pushing up. That experiment had to be done completely on their own at home, and then we discussed it in class and I wouldn't tell them that air pressure was holding it up. They went home and did the experiment and then came back and then we got from them why it stayed on. And of course there were all kinds of ridiculous answers. You know, water acts like glue and so on. But eventually someone realized that we are talking about air in the last two months, begins to put two and two together and figures that air has something to do with it.

I: From the questions and answers that were coming back and forth today, I noticed that they moved towards the results that you wanted them to come up with. It took a bit of doing in some respects, but they did get there. Now do you think they can use that kind of base if they are ever on their own in thinking about science? For example if they had to make a decision, say, between aluminum and wooden storm windows, would they be able to apply the strategy that was used here in science, to the world out there?

T: The scientific method, you mean, that type of thing? I'd love to think so. But it would depend, first of all, on their own basic ability to understand anything. I personally think that some people are more gifted with that kind of thinking than others. I know that I'm not particulary good at reasoning things through and taking the various facts out. I think it's personal in some cases. It's a matter of intelligence too, I think. And a matter of the teaching that they get in the classroom. Hopefully they would apply some of these principles, no matter who they are, to varying degrees of success. Some would obviously get more. Now Michael, who sits there, he's very quick at that. He puts these things together very quickly using that method. Some just don't. He can't read for beans but he's a very logical person. It's a shame. Hopefully, that kind of thinking comes through.

I: That's fine. Now a couple of things about your background. Was this lesson from a particular programme?

T: I believe I'm supposed to follow the STEM series. But I haven't used the book myself, that much, because of my own interests and my own strengths. I have used the book, on occasion, with various classes. But depending on the reading ability of the class and so on, and the interest level, there are some parts of the book that I'm just not interested in, and I figure that I wouldn't do as good a job.

I: Well, is it that this topic is dealt with in the programme, but you're just not using the book, though you are using the topic?

T: I do basically the topics that I enjoy, and that I know I can do a good job with using experiments, because I think that's important for kids. I know kids have been in my class years before and come back, see things going on and say "Oh, you're still doing that old experiment." But they haven't forgotten it. I find the STEM book a little bit haphazard. It does a good job on certain topics, definitely. For classification, I've used it, not with this class, but with another. I use it more piecemeal than as a whole programme.

I: How about the other classes, do they use it?

T: Very little. There is very little science that goes on in this school. It's a shame. Both these cabinets, here, are full of things that I've collected and got from high schools and very rarely is it used or borrowed. It's in my room because I use it the most.

I: So that means that there is no direct input from the science consultant on what goes on in science.

T: He's tried. ______________ has been down. We have done workshops. Most of the teachers are afraid of science. They don't have a background in it.

I: Has there been inservice work here in the school?

T: Yes, there was a workshop years ago, a very good one that Mr. ______________ put on. And I was at one at McGill a couple of years ago that dealt with the same thing, practical applications in the class, many of which I've used.

I: And your background is a B.Ed., a Bachelor of Science?

T: Ah no, I wish I did. I couldn't do the math. I did a diploma at Macdonald and McGill, when I knew you, and then I started doing a degree at night. I started off in science because I wanted to be a doctor, actually, and unfortunately I did two math courses and then I got to calculus and that was it. I was out. I knew I couldn't go on, so that was the end of science.

I: So what is your background in science?

T: My background in science is basically biological. At McGill when I was doing my diploma, I took second year zoology which was fairly complex and certainly enough to teach high school, I would think. I did all the science methods. At Montreal High I took physics and chemistry so I had - - I didn't do well in either one, but I had more than most people had as a background.

I: But it has given some comfort in your work.

T: Oh yes. I don't understand some formulae and the mathematical part, but I understand the theory, hopefully most of them. But the biology I was good at. The biology and zoology were strong subjects.

(End of interview.)

## INTERVIEW WITH TEACHER

## Examination of Cells

(The interview begins.)

Interviewer: The first point that I want you to understand is that the purpose of the interview is not to evaluate you as a teacher and not to evaluate the children's learning. The major point is to determine the context in which the lesson was given. In other words, what the children had had previously, what your expectations were, and what you are planning to do in the future. Just so that, when I analyze the lesson, the interview may give me clues to help me understand what was going on. (T: Yes.) So to start, let's look at your previous lesson. What did you do and what were the emphases?

Teacher: The previous lesson. Now you have the same situation with science once a week. Which comes out to be about an hour, about 45 minutes by the time you get started. We had done - - we talked about cells. Now they had seen those cells in the microviewers, the plant cells first, and we talked about them. The second lesson, we did the cells of the human body, the animal cells and we just discussed them. We discussed what cells are about. And this one was a - - . My objective was to zero in on the two types of cells and have a better look at them, choosing one plant and one animal cell. Sort of a tie in. I don't think I expect things like cytoplasm to stick in their heads. Although it might.

I: It might. Last lesson, did you give them any rules or definitions about the difference between the cells?

T: No. Ah, yes and no. It could have been part of the discussion because I had a lot of questions from them. They asked me a lot of questions.

I: For example, did you tell them what they should see when they look at it?

T: No. No. Although they all saw the nucleus and that's why they knew the nucleus this time, because it stands out. Although I didn't go on to tell them that in the blood cell - - because I had it in the back of my mind to do it this time around. I didn't tell them about the cell wall or the membrance. Let me think. I didn't tell them about the liquid inside. I just said "Go right ahead and have a good look at them. That's what cells are." And many of them said, "Oh, they look like drawings, like paintings." And it's true, they do, if you look at them. And this day was the day to zero in on two cells.

I: So they've done no experiments. They haven't looked at ...

T: The onion.

I: ...a real slide, or they haven't even looked at an onion skin with a hand lens or anything.

T: No. No.

I: So now let's go to this lesson. The purpose was to bring the two types of cells together.

T: Together and for them to zero in on one. On the cell.

I: With what purpose?

T: So they could realize, um, I still don't think that they fully understand it, the whole business of the cell.

I: What do you mean by understand?

T: How really small it is. Maybe we could talk about it being 800x and 900x and 110, but do they really know what it means to be 110 times? Do I know what I mean by 110x? Tell me, how big is 110x? Big, you know, really immense. I don't know whether you want them to really understand that. It's easy to say, double the size. Even up to 10x the size. This is the book, how big would it be 10x? As long as they can sort of see it in the context of their own, they'll understand it. But do we really know that little bacteria as 95 - 2000x?

I: Their sense of size is very limited. It's too abstract for them.

T: Yeah. That's understandable. That of course will be too abstract.

I: Quite early in the lesson, when you were doing this review, you said, "Explain something. How do some of them look?" Now what were you expecting the students to come up with, when you said explain? What did you expect them to do?

T: Oh yes. Last lesson, before they did drawings, they did drawings of cells and they did the nerve cell which were drawings right out of a book. But the whole objective of that was to get the type of different appearances and the structural appearances first. So they did a muscle cell, which is long. They did a skin cell, a round one, and they did the nerve cell. And they drew them. And I honestly was expecting,"Oh yeah, they really come in different shapes and sizes. Some of them are long like sausages, others like squares." And they did look at the end, when they were looking at them, the whole objective was to see how they did look like. Look how, for instance, the onion skin was, sort of a block. We not only looked at the slides, but we talked about the appearances as well and drew some of them in their books.

I: So then the observations that they had made were of crucial importance for understanding...

T: Yes. Yes. To me yes. It did come out partly in that later on with the function being important. What a cell - - what part of the body it comes from. And that, I think was a key to their learning.

I: Now you said that they had come back to the function. They didn't do any experiments and you had never told them about function, the purposes of the cells.

T: No, but we had, part of the discussion, when I was seeing them, we did mention different things. We did look at the leaf cell and I said, "Now look at how different they are structurally from the stem." So it was implied. It was, you know, one of the generalizations that they could possibly make.

I: The suggestion here is that the generalization came because of the repeated observations that they've made of the slides?

T: I think so. Although I don't know with all the kids. And that's the kind of thing that I'd like to - - that's why I realize that instead of going onto organs I think that one more lesson is needed after this one. One more. As a tie up between all of what we've done.

I: What would you do with that? Would you help them in some way account for what they've seen?

T: Oh yes.

I: And how would you help them account for that?

T: I think a discussion would do from the beginning and then it would lead to any problems. But it's kind of hard when you say to a child, "Any problems?"

I: So then would you give them more information?

T: More information, yes. For example, the business about the cell wall, I think that's pat. Although I have to find out again if they understood that, the difference. The structures, the nucleus they remembered. That's fine. It stands out too. Because when they saw it, "Why is that? What's that there?" In some cases they had a heck of a hard time. For instance when they were looking at them. That's why I did choose the cheek cell and the onion cell, because they were easy to see. For instance the bone cells were extremely hard. The nerve cells, although they have a nice drawing in their book, it was just a drawing and it was extremely difficult for them to see it. But it was interesting, when I asked them "O.K. The next three slides, you're gonna tell me where you think they're from." And the muscle cells. They were able, from the drawings that they had done at the beginning of the lesson, they could pick them out. Both the ones that came from the stomach and the ones that came from the leg. They were easy. They picked out the nerve cell quite easily.

I: Well it's different.

T: Yeah. It's totally different. The bone they couldn't figure it out where the cell was.

I: Alright. So you referred to the work-sheet and you asked them to explain the difference. You know your question on that work-sheet said, "Explain the difference between animal and plant cells." So then the explanation would have been just a refresher of what they had seen.

T: Just what they had seen. No more.

I: Well then, what would they need to really understand the basis of science? What kind of experiment, or explanation, or observation would they need to understand what science is all about?

T: Do you mean by - - . That's a tough question, you know that? You mean in teaching? Do you mean in the materials?

I: Do you have to teach something specific for them to have a real grasp of what they are doing?

T: An understanding?

I: Would it come to them by repeated observations? Would they have to have some kind of information to apply, to account for their observations?

T: It depends. It depends on what you're trying to get across. Or it depends on the ideas, the generalizations, if we can call them that, that they are trying - - that you want them to make on their own.

I: This particular kind of information that you are working with, cells. Cells that are going to comprise organs and systems.

T: Sure. Sure. Ok. It's a difficult question. Now we are looking at whether the children understood, or will need to expand more. Is that it?

I: What would they need? Because you were saying that you were sure not all of them understood and what they did grasp was based on what they had seen. What would they need now to have a full understanding of the function of cells, the purpose of cells?

T: I think you have to advance now as STEM does into the organs. Then the organs as part of the system and then the systems working together. I like that approach. I like the beginning of cells into the fact that cells make up an organ which organs then join and make up a system and the differenct systems interact together to form the complete human, or the organism. You start with cells as your building blocks and then you go up.

I: Let's look at the kids. What do you think they feel about the observations that they make? What importance do they put on these observations? What they see?

T: Yeah. What do they see when they see these things? Now you can look at some faces and they are all glowing, and you think, oh my G-d I've got that one. They are really interested. Or you see some that are really struggling with it and they can't visualize. Because the biggest problem is when we have too many different levels in elementary school, even in one classroom. You have so many different levels. How many have really grasped what you are trying to get at? How many need more time?

I: What importance do they place on the work they were doing today? How important do they think it is?

T: About medium important.

I: Do you think that they feel that this is important and this is how science is done?

T: Yes and no. If you're asking hypothetical questions, I can only answer by yes or no. I found, along the line, in teaching science that certain kids get "keyed". Like a key, you open something. For example, at least ten loved it. We did an experiment on starch. We did a controlled experiment where we took starch and water and we added iodine and it turned purple and then we did no starch just water and added iodine and it turned a rust colour. And we did it on foods. Now children were bringing in all kinds that they wanted checked. That type of experimentation where they saw the results immediately was great, for some. Others liked to look at slides and things. It all depends on the approach and the type of approach the child likes. So what I'm really saying is that in differing the approach, you are gonna catch certain children that like it. There are some children that I don't think like to do experiments. Not all children are experiment minded. I think some children like to sit back. Some kids are great at discussing, their hand is up all the time. Some children don't like to work in groups. Some do.

I: So then to go back to the way in which the lesson was carried out, what you're saying is that some children prefer to have this back and forth look, a little bit of input from the teacher and then look back to see, to corroborate really, what has been said. Rather than having them look at it without help.

T: Uh huh, rather than having them look at it and come up with those terms.

I: But there was a point when you said, I think they were still working on the work-sheet, and you said, "Everybody has to discover it on their own." What did you mean by discover?

T: Oh, that was when I was walking around...

I: ...they were looking at the two cells on the work-sheet.

T: Oh, that was because someone was looking at----.

I: Oh, so that was the only association with discovery. It had nothing to do with understanding what was going on.

T: No. No. I pointed to the top cell and the bottom cell and I said - - and someone right beside that said - - and I said no, no, everybody has to discover it on their own. In other words, don't give him the answer.

I: Let me have, if you don't mind, a little bit of information about the programme that you are using. Did you have any in-service on the STEM programme?

T: No. I didn't.

I: So, how much imput did the consultant have? Did he come in at all? Did he give you any instructions on how to teach it?

T: Not me personally. But I am working on the Science Committee (of the Board) with him, which is really an advisory council. My background is science, geography and biology really, so that I'm able to adapt to a programme like that. I like the programme.

I: What's the advantage of this programme over another one?

T: Quite numerous, the advantages. I think, #1, the programme goes from K to grade 6. And that means a sequence. When you are using it once a week, a sequence is important, especially level after level. I think another one would be the fact that STEM exists in French: "Les chemins de la science" which is published by another company, but the same book, so we can use it in the immersion stream and not break the sequence. It deals with numerous topics. My field may be biology and I just love zoology and so I love cells and I do all cells. It deals with most of the sciences, with physics, zoology.

I: What's the philosophy of the programme? Where is the emphasis in the teacher's edition? Is the emphasis on the teacher, on the kids or on a combination?

T: It's about 50/50. There are activities for children to do. There's even in there I think, discovery that you can use, sort of, like that lesson today was not from STEM. That was something that I had thought of because I found STEM weak there. I did talk about cells and we got to the fact that they really didn't do an adequate job on the cells so I had to go home and think up something else. I was not too pleased with just showing the children what cells are. I think zeroing in on two. Because they did show, and then in one instance they said well - - they didn't even make too much sense in the difference between the plant and animal cell. The fact that the twig breaks doesn't mean anything. How about bones? Bones are pretty solid material. And I didn't like, for instance, the analogy at the end that enables humans to move or animals to move or plants to remain there. I like the series because it blends a little bit of every type of science. It's not up to the elementary school to zero in on biology or to zero in on these subjects.

(End of interview.)

## INTERVIEW WITH TEACHER

## Batteries and Bulbs

(The interview begins.)

Interviewer: Before I start with some questions for you, I would like to recall the actual purpose of the interview. This is basically to establish the context of the lesson and to try to grasp some of the Ps' prior understandings so that I can analyze the lesson more clearly. The purpose is not to evaluate you or your technique in teaching and certainly not to examine the Ps' learning. Some of the questions may be a little pointed, but it's to help me understand what has occurred in the classroom. I'm going to make some references to the lesson because I had the transcript in front of me. Now at one point in the lesson, a reference was made to the intensity of the light of the two different bulbs and the use of the light meter, yet when the lesson started there was no explanation of the purpose of the light meter. So have the children had any prior understanding of the purpose of the light meter, for example, in a previous lesson?

Teacher: The light meter was prepared two weeks in advance. One week we prepared the light meter. The previous week we worked with the BP and BW bulbs and they did find - - they did research on - - looked at both bulbs to see the difference with the light meter. So that had been done in a previous lesson, so they knew at that point - - they should have known what the light meter was for and how to handle it.

I: Did they understand why the lights were being tested for the difference in intensity?

T: It was to use - - later on we wanted to decide which ones we would use for the, um, not the magic boxes, but for the, ah, boxes that they...

I: Electrical game boxes that they make?

T: Yes. That they would know. This was the reason. And they decided they would use the strongest ones for our games.

I: Later, after that, when the children set up a series circuit and they again examined the light intensities in series, they were told to find out why there was a difference in the intensity.

T: If there was one.

I: Or if there was one, and if there was, why. To discover why.

T: Yes.

I: And yet, at the end of that portion of the lesson, when the children were finishing there was no explanation, no discussion about it. Now, I'm wondering whether you feel that the kind of experimental activity they were involved in, that alone, would generate an understanding about the intensity of light in a series circuit?

T: No, because this is mostly research. They have to find out for themselves and I find this is one problem with the series (programme). It's experimental. You find out for yourself. There are very, very many ideas, but there's no theory in any of this. There is not enough theory in this bulb and battery unit or any of the units we have. It's completely visual and experimental and as far as the basic theories - - .

I: Alright. Now, if the programme does not provide it, how do you feel about it? Should experimental inquiry be the important aspect of scientific understanding for the children or should there be theoretical input to help them?

T: I feel there should be more theory put in because all the experiments have been done previously. And the children are not discovering anything new. They are only doing what we're asking them to do, but all the research and all the - - they don't invent anything. They won't come across anything great. They know it exists. They've had Christmas trees since the day they were born. They know a series in lights and the difference - - .

I: In other words, they've had other experiences with this.

T: Yes. They've had so many experiences in their previous lives, they understand them. But the thing is, as far as theory, what they need is theory and they do not have that with this system.

I: How would you, if you had the chance, how would you combine the theory and this kind of activity?

T: Well, I would do more research on the inventors of all this, first. I'd start with Weber, you know. Let the children do the research.

I: You mean history?

T: History. The background. Get more background on it. And then of course, they could see it's true. Now whatever they gave us, it does work. We can do this, this, this with it. We have other series. We have the pendulum that can be taught in two afternoons and it costs hundreds of dollars, and there's no theory to it. Now, if they would go back and give us more theory, instead of just saying you try this, see how far that swings back and forth. There's a link missing, an important link, especially at the elementary level.

I: If this link is missing then - - let me see if I've got it. Are you trying to suggest that it would be better for the children if their experimental activity included both the experiment, the discovery and the observation, and the theoretical input, to knit the two together?

T: Yes. To me this would make more sense.

I: Would they understand science better then?

T: Well, they would, because they would have the background, the history of it. It's like trying to repair a car, if you don't know what a car is all about - - .

I: Let's move onto the next section of the lesson. At one point the children were working quietly and they were still working with a series circuit and there was a - - you started to say, "What happens when an experiment doesn't work?" and then, there was nothing after that. The pupils said "It worked." "It worked, it worked, Miss." What did *you* have in mind?

T: I had in my mind - - I was expecting the children, one of them, to come up and say well maybe the battery is not good or give some reasons why. But they all said it worked. They weren't worried about that. See, because, - - this is one thing about this - - there is a lot of playing. They play. They enjoy it. They're not too interested in the science of it. If it works, it works. But when I mention - - for example, one day I wanted to tell them about a light bulb. What would be the reason why a light bulb would not light and how do you know. How you would know. And I couldn't get any - - you know - - for them to say, "Well there was no power running through it" or "Maybe it wasn't in the socket properly" or for different reasons, they don't - - .

I: How do you account for that?

T: I don't know. Honestly.

I: Surely they've had other experiences at home. Why couldn't they draw from those experiences they've had?

T: The only answer you get is, "I don't know", or "You know".

I: Do you think the pupils need some kind of rules, um, not rules of behaviour in the classroom, but rules in science. For example, you gave them the rule for making the parallel circuit. Could they use more rules of that nature?

T: Well, I believe so, because they seem to lose - - . I'll give you an example. The very first day, when I began this battery and bulbs, I never tell them what I'm doing or why because they have to find for themselves what, you know, what they should do.

So the very first day I gave everybody a bulb, a battery, a wire and that was it and I said, "Now light it!" and that was it. "I don't care how you do it, find a way." And this is how the programme is. So you see they had to take the wire wherever they could on the battery so it took quite a while because they had no ideas what to do with it. Two or three got it, but the rest - - that was it. So naturally they, you know, didn't want to play. No matter how much you try to get them to settle down and say this is science and try to get them to see which end, for example, of the battery should the wires be, will it work elsewhere, if not, and - - . No, there's something missing, for sure.

I: Yes, that's precisely what you did do. You gave them the two copper wires and you said, "Now you've got to find out what to do with them." And yet they played around with it, and the girls on this side, they made the parallel circuit quite quickly. Um, and yet, some of the others didn't.

T: Even with the cue I gave them...

I: Even with the cue.

T: ...that I was looking for a parallel.

I: You said that they had to go back to the source of power.

T: Oh yes, that's right.

I: And that was interesting because some did go back to the source of power, but differently. So then, you're suggesting that rules, some kind of rules, would be a good idea for them.

T: Oh yes.

I: I was wondering whether they had done parallel circuits before. Evidently not.

T: No.

I: Yet, you said that you had mentioned parallel circuits right at the beginning.

T: When we were - - when I introduced the - - afterwards I mentioned the different things we would be doing with the - - . I always give them an idea of what's coming.

I: So they couldn't make the association because they weren't really certain what to do.

T: No, they didn't know what was coming.

I: A number of times throughout the lesson, certain terms came up, such as circuit, power, separator, you know, the glass separator between the filaments of the bulb; series, parallel circuit. One of the youngsters mentioned short circuit. Were these terms ever explained in previous lessons?

T: Yes they were. Because we did the bulb itself, and we diagrammed the bulb and I had the overhead projector and I had several bulbs, two clear ones, and with the overhead projector they could see where the link was missing, where the power was broken.

I: Now, was this given to them as explanations or as definitions?

T: Ah, the ah - -.

I: These terms, for example, what the separator is for, what a circuit is.

T: No, they just called it a little glass bead in the middle and eventually I gave them the name of separator, because we used it for labelling. Then I gave them the proper terms.

I: So they really gave it a label and then you gave them the correct term.

T: But sometimes they say 'sketch' and I would say 'diagram'. They would say a 'bead' and I'd say a 'glass separator'. Along that line.

I: With these terms: power, series, short circuit, was there any activity carried out before or after the term was given?

T: No. It was before tne term. The term is only given when it comes time to label in the copy book, to give the proper term.

I: So they first do their exploration and then you give them the term.

T: Right. They don't know the terms when they start.

I: If you had to do it in you own way, would you still follow the same procedure?

T: Along the same lines, along the same line I would, only I would, only I would give them - - I'd have them do a little more research on electricity.

I: Just a little while ago you mentioned that you found the children carried out the science as if it were a lot of fun and enjoyment for them. Do you think that the pupils themselves place any particular importance on observing the kinds of science events that are happening?

T: I feel it's a game.

I: You mean that they look on it as a game?

T: Yes.

I: So they don't look at it towards any kind of understanding of what they are doing?

T: Well, they understand what's going on, but it's not deep at all. It's not something they have to study.

I: Have you ever tried to provide a theoretical background?

T: I do, when - - not the best, but I do when I - - before we go to the planetarium. Then, of course, we do quite a bit of research. I have them do research on it.

I: Do they prefer that?

T: It depends. In the class, I might have about 10 who would prefer that type but the others are perfectly willing to just go along as they are, because it means studying. It means more work. It means books. That's why they enjoy this so much, because it's not - - they don't have to study for it. They don't have to read up.

I: What do you plan on doing in the next lesson?

T: The next one - - I haven't finished now with the - - we have to compare the parallel and series.

I: And what kind of comparison? Do you mean the intensity of the lights?

T: Well yes, the lights, and then afterwards we'll start working on our mystery boxes. We haven't worked on mystery boxes yet. Now this is where we find - - the mystery box - we'll have simple, very simple ones. But then one or two might go into very complicated types.

I: Now if the children have to connect the mystery boxes that means that they have to have understood the different circuits.

T: Oh yes.

I: So, from your experience, have they indeed understood it and been able to transfer their knowledge?

T: There is a difference, now, of their understanding from the first day when they came in with only one wire, the battery and the bulb. Definitely that. They have learned this much.

I: Do they have any conception of how scientists carry out their work?

T: Yes, well, I don't know whether they have or not, but I did explain to them at the beginning the importance and that even if some of my questions were quite silly to them, that they didn't think they have any value, such as for example, the light bulb -- they might feel that they're silly questions, but really it's quite serious - - .

(End of Interview.)

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# APPENDIX C

## Study Review and Instructions for Independent Judges

## Review of the Study

The purpose of this study is to explore the development of a scheme for the systematic analysis of science lessons in elementary school. This investigator claims that the clues or characteristics of the analytical scheme are recognizable in the dialogue of a lesson thus enabling one to identify a particular conception of scientific inquiry that is being conveyed. This argument is derived from the view that science teaching has the potential for conveying substantive ideas about science to pupils during lesson interactions even though neither the teacher nor the pupils may be cognizant of the substance of these messages. Because of this "uptake" by pupils, it is suggested that such an analytical tool may be useful to practitioners who, in examining science teaching, need to make rational choices about the nature of the scientific ideas to be conveyed to elementary pupils.

The scheme consists of three conceptions or views of science which are characterized through three categories of science activities. The characterizations, then, serve as the clues to identify how the activities of observation, experimentation, and explanation are carried out under the influence of a "Sensationalist", a "Formalist", or a "Via Media" view of science. The descriptors of the scheme are described below.

### Three Views of Science

The analytical scheme, as developed here, derives the three views of science from the work of N. R. Hanson. These are the polar views of Sensationalism and Formalism and a middle or balanced view, the Via Media. From the point of view of this philosopher of science, the conceptions of science refer to the activities of scientists. The study, however, argues that the same views of science can be identified in the language of science teaching and in the emphasis given to certain science activities in the elementary classroom.

Briefly, a sensationalist view is conveyed during science lesson when pupils are expected to gather as much data as possible through sensory perceptions and experiences. It is this kind of personal information, rather than scientific knowledge and theory provided by the teacher or other sources, to which pupils refer when talking about and making sense out of science events. At the other extreme, a formalist view of science is conveyed when sense data and experiential familiarity is of little consequence. Rather, certain teacher expectations and scientific knowledge are more important than pupils' experience and these determine how scientific events are to be understood and talked about. In developing the analytical scheme, definitive clues which correspond to the balanced view of science were not identified. However, this investigator did find evidence that such ideas were being developed during the lessons. Hence the clues referred to are considered to be precursors or forerunners to such ideas. Thus, a via media view of science is conveyed when there is evidence that connections are being made between the pupils' experiences and their limited knowledge, with the teacher's own information and understanding about science. This may be manifest by the way in which the teacher "sets the stage" for pupils to recognize certain data or experiences as relevant. Further, pupils appear to apply certain constructs from prior scientific understandings to new but similar problems or events.

## Three Categories or Science Activities

The theoretical portion of the study argues that Hanson makes distinctions between three views of science by describing particular activities of scientists. Since the experience of this investigator indicates that the same kind of activities are commonly found in an elementary classroom, the clues of the scheme are derived from analysis of classroom discourse and refer to three such distinguishing activities or categories within each view of science.

At the level of elementary school children, observation refers to any activity in which pupils use all of their senses or observation-enhancing tools such as lenses or microscopes. Experiment refers to any type of investigation of scientific events. At the level of school children, this could mean a whole range of activities from mixing of substances to carrying out controlled experiments. The language of the classroom is most evident in the lesson interactions and explanation is closely associated with the understanding implied by the terms used and the manner in which the teacher and the pupils make sense out of the problems and events experienced.

In developing the scheme, the investigator notes in the study that the interrelatedness of these activities in an elementary classroom makes them difficult to isolate. Furthermore, the scheme reveals that clues for one activity tend to be repeated for another activity associated with the same view of science. For example, clues which reveal sensationalist ideas appear to be repeated for the activities of observation and explanation. Notwithstanding such difficulties, retaining clues for identifying two levels of thought enables one to distinguish between a wider range of possible ideas about science at the same time as maintaining the integrity of Hanson's work.

## Clarity of the Scheme

This investigator claims that the clues of the scheme are sufficiently clear to be recognized in the dialogue of a lesson as conveying one of the two polar views of science (sensationalism or formalism), and as developing toward a balanced view of science (via media). The scheme further reveals that more than one view of science may be identified in a single lesson irrespective of the varied activities carried out. For example, one portion of a lesson dialogue may manifest the clues identified with a formalist view of scientific explanation whereas another episode of the same lesson may reveal that a sensationalist view of observation is being transmitted to the pupils.

In order to be certain that the clues of the scheme correspond to the views of science identified, the investigator recorded and analyzed an interview with the teacher of each observed and recorded lesson. In this way the context in which the activities of the lessons were carried out contributed to the development and the support of those clues which comprise the scheme.

Nevertheless, it is necessary to determine whether the clues so developed can be recognized in a lesson by a person who does not have the personal experience and knowledge which this investigator brings to the application of the scheme. Thus two independent judges are asked to analyze a transcribed science lesson by using the scheme as indicated. The analysis and comments will be compared to those of this investigator to determine how well the clues are revealed in the lesson.

## Instructions for Applying the Analytical Scheme

1. The judge is requested to read the entire lesson prior to analysis in order to become familiar with the topic and the "flavour" of the interactions.

2. The Analytical Scheme should be examined carefully so that the manner in which the clues are associated with both the science activities and views of science is clear.

3. The code to be used indicates the particular clue or clues which correspond to a view of science being conveyed by that portion of the dialogue. For example:

    S-a, S-b, S-c, refers to those clues which reveal sensationalist ideas about observation, experiment, and explanation respectively.

    F-a, F-b, F-c, refers to those clues which reveal formalist ideas.

    p-M-a, p-M-b, p-M-c, refers to those clues which are considered to indicate a development toward a via media view of science.

    Note that use of the letter "p" in this particular code differentiates it from the others. Since clues revealing via media ideas were not clearly identified, this code makes it easier to talk about clues which indicate that such ideas are evolving or are being developed in the dialogue.

4. A sample analyzed and coded lesson is provided to show how the clues of the scheme have been identified in a lesson. This analysis should be carefully examined prior to application of the scheme to the unanalyzed lesson.

5. The lesson to be analyzed has been divided into episodes for convenience only. These episodes serve to make the analysis more manageable and to mark a shift of topic during the lesson. The analysis may, though, be carried out by episodes providing the judge realizes that the dialogue of a single episode may

reveal clues which indicate more than one single view of science. The scheme, then, should be applied to all portions of the lesson where the clues are recognizable in the dialogue. Procedural matters or classroom management such as quieting classroom noises or homework assignments are not amenable to analysis and should be noted as such.

6. If one episode is found to reveal a single view of science, it would be appropriate to indicate this judgement by inserting the code beside the heading of the episode. If the episode reveals that more than one view of science is being conveyed, this could also be noted, with the secondary view in parenthesis. For example:

   Episode IV: S-a
   or
   Episode V: F-b; (p-M-b)

7. The analysis should be written in the right hand column of the working copy, beside the transcribed lesson.

8. The judge should insert the code indicating the lines of the dialogue to which the clues apply. A brief reason should be provided as to why the clue or categorization was chosen. For example, if the dialogue between lines 5 and 10 reveal a clue (or clues) suggesting a formalist view of explanation, then this portion of the dialogue should be coded as follows:

   LL.5-10: F-c

   T insists that only
   one particular answer is
   acceptable.

   Reference to page and line numbers should be noted as follows:

   p. for page; L. for a single line; LL. for
   more than one line.

9. When the entire lesson has been analyzed and coded, the judgement should be checked and transferred to the final copy of the lesson. The judge is requested to write out, on a separate sheet, any difficulties encountered in recognizing the distinguishing clues. The investigator would welcome any suggested additions to the scheme or changes in the clue structure which would substantively improve recognition of the views of science being conveyed.

10. The sample lesson, the completed analyzed lesson with the reasons for the categorization, the analytical scheme, and the sheet of additional comments should be returned to the investigator.